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PROCEEDINGS OF THE

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

PRESIDENT'S ANNUAL ADDRESS.

SOME MODIFICATIONS IN BLAST FURNACE CONSTRUCTION.

BY JULIAN KENNEDY,*
Retiring President.

January 15, 1907.
President S. M. Kintner in the Chair.

Within the last twenty years American Blast Furnaces have increased greatly in size and output. In the same time there has been a marked change in the raw materials used in them. Owing to the enormous tonnages made, it has become necessary to use in addition to what are known as the old range ores, which are coarse and lumpy, a large proportion of the Mesaba Range ores, which are comparatively fine and dusty in structure, and which have a tendency to interfere with the free passage of the blast through the furnace, and to cause the furnace to work irregularly and to hang and slip. This hanging and slipping causes a variable pressure in the bottom of the furnace and also causes great disarrangement of the stock descending in the shaft of the furnace. When a furnace is working normally, the blast pressure drops gradually from

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the level of the tuyeres up to the zone of fusion, or say six feet, above them, where there is a rapid drop for a short distance and then a gradual drop from this point to the top of the furnace. The blast pressure in a normal working furnace is shown in a general way in Fig. I.

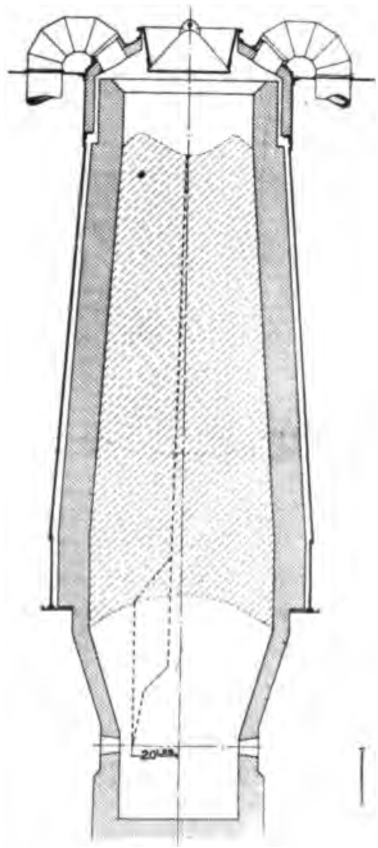


FIG. I.

When a furnace is hanging, especially if it stops moving for a considerable time, the stock burns out below, leaving a cavity, and anyone who has examined a furnace which is hanging, by taking the blast off and looking through the cinder

notch or the tuyere with the aid of a mirror, can see this cavity very readily. In the case of a furnace hanging stubbornly, the cavity will often be formed about as shown in Fig. I, the interior of the arch looking quite smooth, due to fusion going on at this point.

After the cavity reaches a certain size a portion of the stock is liable to drop, breaking the arch and causing the stock above to come down with a rush. At the same time the compressed air in the cavity at the bottom of the furnace is released, and goes up through the falling stock with a tremendous rush. If the top of the furnace is constructed as shown in Fig. II, having its hopper and cone set on the brick work and held almost entirely by its own weight, this rush of gases is liable to lift the entire top up or perhaps throw it entirely off the furnace. It was formerly the practice to set the hopper in a base ring resting on the brick lining alone, but as the lining sometimes disintegrated and allowed the hopper to drop into the furnace, brackets were added to prevent this, as shown in Fig. II, and later the hopper was bolted down to these brackets or to a frame of beams which took their place. To prevent the upheaval of this bell and hopper apparatus, so called explosion doors were placed on the downcomers, and in some cases extra openings were carried out through the casings and additional relief doors were fitted to these openings. In the case of heavy slips where heavy pressures and large volumes of blast are used, the upward rush of the blast picks up the ore and coke and carries it up with it and hurls it out of the relief doors in great quantities, it being not unusual to see from 30 to 50 tons of ore, coke and limestone thrown out of a furnace in less than as many seconds at the same time that a vast cloud of gases and ore dust envelopes the top of the furnace, and some times these gases light as they come out, making a tremendous flame.

About seven years ago it occured to me that, if possible, some method ought to be devised to prevent the terrible loss of life on top of furnaces that was going on, due to men being suffocated or burned on the tops of furnaces, as well as the

loss and damage caused by the throwing out of material at the relief doors. After studying the matter for some time I concluded that there was no good reason why the usual explosion doors should not be omitted. It seemed to me that

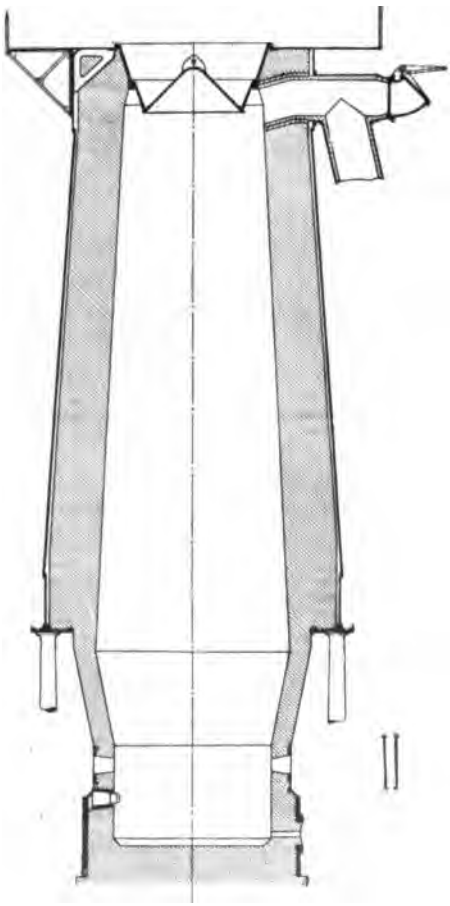
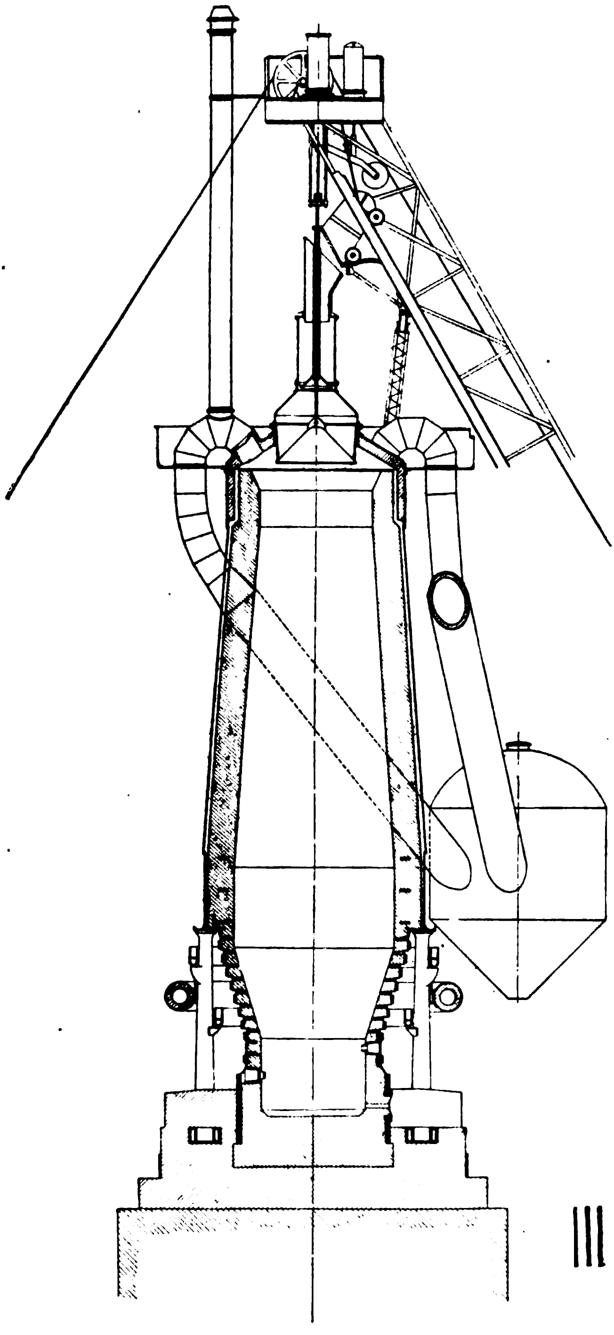


FIG. II.

what was usually spoken of as an explosion following a slip, was not an explosion at all but that the material thrown out was carried up by the rush of the blast in just the same manner that dust or grain is carried in a pneumatic conveyor. The

fact that bells and hoppers were thrown off furnaces by slips, appeared to point to very high pressures until I had figured the amount of pressure required to throw up these hoppers, and somewhat to my surprise I was not able to find a furnace in the United States whose top would not be lifted by a pressure of two and one-half pounds per square inch. After giving a good deal of thought to the matter, I formed the opinion that the ultimate pressure which could be produced in the top of a furnace following a slip, would be the pressure in the blast main, or in other words, that the pressure in this case comes from the blast engines, and the stream cannot rise higher than its source. It also seemed to me that if the furnace casing were made strong enough to resist this pressure, it would be entirely safe to reduce the size of the outlets to such an extent as to offer a material resistance to the flow of the gases from the furnace in the event of a sudden and heavy rush of blast through the furnace, and that such a choking of the gases at these outlets would greatly diminish the rapidity of flow for the moment, and thus reduce the tendency to carry solid materials out of the furnace. The first furnace built carrying out these ideas was at the Iroquois Iron Company's works, Chicago. It aroused a great deal of interest, and the great majority of furnacemen who saw the plans of the furnace, predicted that the top would blow off the furnace in a short time after starting. Others said either the top would blow off, or the bosh would be blown out. None of these predictions have come true. The furnace stood the heaviest sort of slips, and a slip that on the ordinary furnace would have thrown out twenty tons or more of stock, would not throw three hundred pounds of lumps into the dust catcher. The fact that the rush of gases is controlled to a certain extent also causes less disarrangement of the stock in the furnace, so that with a slip of a given magnitude there is less derangement of the working of the furnace and less tendency to change the grade of the iron made. There are now in operation twenty-four furnaces of this general construction, shown by Fig. III. Wherever possible, I have installed them without re-



III

lief doors on gas mains, though in some cases, owing to insistence of managers, who were "almost persuaded" that the general scheme was all right, I have had to put on relief doors on dust catchers or on gas mains. In some cases no relief is given except at stove and boiler burners and at bleeder, and in some cases the bleeder has a positive valve so that the only openings for the passage of the gases are those of the burners at boilers and stoves.

These furnaces have demonstrated, beyond a shadow of a doubt, that it is absolutely safe to altogether close the top of the blast furnace, and that the letting loose of great volumes of dust and lumps of stock at this point is entirely unnecessary. It has been said that even if the dust is all brought down the downcomers, it will pass through the stoves and boilers, and thus be scattered over the surrounding country. Some of it of course will, if no arrangements are made to stop it, but a large proportion of it can be caught in very simple dust catchers, and since gas engines have been installed at furnaces, there have also been started gas washers so perfect that they will take gas from a furnace running on a mixture consisting largely of Mesabi Ore and cleanse it till it has less dust in it than the ordinary atmosphere. So that given a device that brings all the gases down to the cleaning apparatus, it is entirely feasible to do away with the dust absolutely. As far as I am aware, not a single man has ever been burned on the top of any of the above mentioned twenty-four furnaces, or burned or injured by material thrown from their tops; nor have any of them bursted at any other place, or shown any indication that the strains on the bottom of the furnace have been increased by closing the top. In the light of what has been demonstrated, there surely can be no excuse in the future for burning men on top of furnaces, or burning or otherwise injuring them with materials thrown out of the tops of furnaces because of slips, and the amount of dust sent out from a furnace will depend entirely on how perfectly the management choose to cleanse the gas by means of dust catchers and washers, which have at the present time been developed to a

degree of perfection which will enable the top of a furnace draft stack to be cleaner as far as dust particles are concerned, than the cleanest spot in Pittsburgh is at present.

DISCUSSION.

The Chairman: I am sure you have all enjoyed this most interesting paper, and it will certainly suggest a number of things that you would like to ask Mr. Kennedy about more particularly. The paper is now open for discussion.

J. O. Handy, Member: I would like to ask if fire brick in the upper part of the furnace where they are acted on by the gases are also sometimes disintegrated or rotted, as well as the iron and steel?

Mr. Kennedy: Not if the brick is free from iron and is of a good quality. Brick that has too much iron in it will sometimes disintegrate: There have been cases where brick in the upper part of the furnace have disintegrated but with good fire brick there is not much trouble that way.

A. E. Anderson, Member: Has the gas engine in connection with blast furnaces been developed enough to say that it will be a settled practice in the future?

Mr. Kennedy: I think that it undoubtedly will. It is coming very rapidly, and one of its good features is that it will cause people to clean their gas.

H. D. James, Member: I would like to ask if there are any furnaces in the Pittsburgh District equipped with this construction?

Mr. Kennedy: Yes, the Isabella Furnaces, the Clairton Furnaces and the Donora Furnaces.

E. K. Morse, Member: I would like to ask him to explain a little more of the modern furnace, and especially how much of the finer material and the lighter coke will go down the downcomer, if any, and what the action of that is when the pressure does not reach the top. We know that with the ordinary furnace it blows out great quantities of fine dust to a distance of a good many hundred feet. I would like a little more explanation of the action of the top of the furnace.

Mr. Kennedy: The action of a furnace equipped with relief doors at the top, like the one shown here, is that while throwing out a large amount of material through the doors, it will also throw a considerably larger amount of coarse material into the dust catcher than will the closed top furnace which cannot throw any material out at the top; that is, a furnace of the open top kind which throws two or three car loads of material through the relief doors will also throw much more material into the dust catcher than the closed top furnace will, with the same sized slip. Of course both tops will throw considerable fine dust over into the dust catcher, but the closed top throws a good deal less coarse material, and I think less fine material, as well. In any event, whatever is thrown out is thrown into the dust catcher, and does not come down on anyone's head, so that the men around these furnaces or working on top of them, need pay no attention to whether they are hanging or slipping or not. Whereas with the old kind of furnace the man who goes on top when the furnace is hanging badly, takes the chance of being burned to death whenever he does it.

Mr. Morse: But closing the top of the furnace, or throttling it, holds the pressure down until there is time to equalize it and as a matter of fact less dust is moved entirely?

Mr. Kennedy:. Very much less dust, for the same reason that the waiter who pulls the cork entirely out of the bottle, loses half the ginger ale, while the fellow who pulls it gradually does not lose a particle. It is like a triple expansion engine, when you get a high pressure of steam in the cylinder and receivers you cannot stop it instantly by throttling it at the usual point, but the steam in the receivers will go on through, and the engine will race unless you throttle it further along; and when you have 20 feet of the bottom of the furnace filled with compressed air, and that breaks up suddenly through the stock, there is no way to check it at the bottom, but you can throttle it automatically at the top if you make the exit as small as will allow the gas to pass through it during ordinary working. In this case, when there is an extraor-

dinary rush of gas, the resistance of the small opening automatically throttles and holds it back, and for that reason it does not gather up and bring with it near as much material as when a large free opening is left for it. Slips which are of such extent when determined by measurement, as would in an ordinary open type furnace throw out twenty, thirty or forty tons of material, will not throw a tithe of that amount into the dust catcher in the case of the tight top furnace.

A Member: Would that system prevent the terrific distribution of dust?

Mr. Kennedy: It would prevent all egress of dust through the top of the furnace. Of course dust comes down into the dust catcher, and if the gas is not cleaned properly it can pass through the boilers and stoves and get out at the top of the smoke stacks, but all dust that comes out around the top of the furnace is absolutely done away with. You could go by furnaces of this kind on a train and in many cases could not tell whether they were running or not by looking at the furnace, and the only way to judge would be to look at the top of the smoke stacks and see if there was any smoke coming out there.

Mr. Morse: Where are those furnaces you mentioned in Buffalo?

Mr. Kennedy: At the Buffalo & Susquehanna Iron Company's works. There is also the same at Punxsutawney, Du Bois, Cleveland, Toledo and two at Chicago.

Mr. Anderson: Is the electric furnace making any progress such as will make it a competitor of the blast furnace?

Mr. Kennedy: Not yet for the production of ordinary grades of iron. The electric furnace has a field in the production of high grade special steel, such as tool steel, and steel for automobiles, but it cannot as yet compete with coke for the production of ordinary qualities of steel in large quantities, except under very extraordinary conditions as to water power. But even at the price charged at Niagara now, it cannot compete with the blast furnace in making ordinary material.

H. C. Babbitt, Member: I would like to ask if you do not think the future economy of the blast furnace will depend in great part on the utilization of the clean furnace gas. Calculations I have seen state that to-day there about twenty to twenty-five horse power per hour thrown away in gasess for every ton of pig iron made per day. If I remember rightly I think it was Sir William Ramsey who was so radical that he stated that in the future the blast furnace would be run as a gas producer and pig iron would be a by-product.

John A. Brashear, Member: Sir William Ramsey uses pretty large statements sometimes. That man has done great work in the world, but he occasionally gets wild.

Mr. Kennedy: The gas engine using furnace gas produces about three times as much power as can be produced by putting the same gas under boilers, so that there is now a very distinct movement toward gas engines. The Edgar Thompson people are putting in some and the new plant of the United States Steel Company at Gary will have almost entirely gas engines. They will have a few steam engines for the purpose of starting up, but the bulk of the power will be furnished by gas engines, and in addition to blowing the furnaces power will be furnished from the furnaces to run the mills, which will be driven by electricity generated by gas engines; so that the only fuel they will use in the steel mills will be for heating the steel. The statement that pig iron will be a by-product is perhaps not so wild as it would at first seem.

Mr. Babbitt: Do you think that is a fair figure, 20 to 25 H. P. per hour for every ton of pig iron made per day given off in combustible gases?

Mr. Kennedy: Yes, I judge that the figures named are approximately correct.

Mr. Brashear: Do blast furnaces generate power in excess of what they need for their own immediate uses?

Mr. Kennedy: Yes, even with steam there is quite an excess of power. At the Duquesne Works you will see a line of pipe laid from the blast furnaces to the mill, and they

get probably 2,500 H. P. If they had gas engines they would get many times that amount.

L. A. Starrett, Member: Speaking of the present boiler equipment of the Gary Plant, its equipment will amount to about 6,400 H. P. for the entire plant.

Gerald Flanagan, Member: When the stock in the furnace has been hanging a long time and is arched over as he describes, I would like to ask Mr. Kennedy, if when the slip occurs, does that slip extend to the top of the furnace or does it arch over at some intermediate point again?

Mr. Kennedy: I think as a general rule, the whole charge comes down. It starts to fall from the bottom, and it may be several seconds before it all gets down. I knew a man once who had the theory that if he could get an enormous opening in his furnace, he could do away with all danger from slips. So he cut out not only his downcomers but about six other openings, four or five feet in diameter, as many as he could all the way around, and he got the aggregate area of the openings equal to the area of the cross section of the furnace at the bosh, and he thought he had a model furnace. These openings had doors to hang shut, which would open when there was a slip. They had a slip, and before they could stop the blowing engines they had emptied that furnace to within twelve feet of the tuyeres. It had simply been poured out over the casting houses.

Mr. Flanagan: That seems to bear out what you said about the material being thrown out by the blast pressure and not by any kind of explosion?

Mr. Kennedy: I have never seen in a slip anything that to my mind seemed to be explosive. There have been explosions in furnaces when blown out, and when nearly empty a lot of air possibly got through the thin incandescent bed of fuel without being burned and mixed with the gases above, and then the whole business exploded. That was an explosion, and the bell went up fifty or sixty feet, and the jacket was rent open and all that sort of thing. There is no doubt of an explosion when it comes, and we will always know it.

A. Stucki, Member: It has been proven that furnace gas can successfully be used in gas engines, since we know how to wash it; also that gas directly used is far more economical than steam. But what I would like to know is the amount of heat units contained in the furnace gas with the point in view, whether it could not be used for commercial purposes.

Mr. Kennedy: I imagine that blast furnace gas is rather too weak to be used in this way. It has not much illuminating power, and has not heating power enough to use, for example, in open hearth furnaces, but it is an ideal gas for gas engines, simply for the reason that it is not so strong as some of the other gases. It would not be suitable for distribution in mains through cities, and the best possible way to use it is in gas engines at the furnace.

Mr. Babbitt: I could tell Mr. Stucki that the average blast furnace gas will run about one-half per cent. hydrogen and 27 to 28 per cent. of carbon monoxide. It has a value of about 85 to 90 heat units, while natural gas, which is practically all CH4, will run over 1,000.

Mr. Kennedy: I might also say here that in the Gary plant it is my understanding that the gas will practically all, except what is used for the blowing engines, be turned into electric power, and the rolling mills will be run by electric motors and not by direct connected gas engines.

K. A. Muellenhoff: I might call Mr. Stucki's attention to the paper read before this Society in 1903, where all these figures were given in detail.* I would like to ask Mr. Kennedy if, in this throttling of the gases, there is diminished to any appreciable degree this turning up and down of the whole charge, so that the working of the furnace is kept almost uniform, even if a slip occurs.

Mr. Kennedy: I think this action is materially diminished; I would not say that it is done away with. There

* Gow and Flint. Vol. XIX., 1903, p. 195f.

must be quite a disarrangement in any case; but with the semi-control which this gives when a mass of this kind breaks loose and comes rumbling down, my observation has led me to believe that there is a material lessening of the disarrangement in the furnace and that there is somewhat less danger of making white iron the next cast.

Chester B. Albree, Member: With a blast pressure of say 500 tons, what is an average charge; that is the material in the furnace at one time, in tons? To get an idea of what mass would fall if there were an arch formed there.

A. E. Anderson: In view of the fact of the Connellsville coke having a rather short existence, will not the future require a modification in the height of the furnaces to meet the weakness of coke made from inferior coal as compared with Connellsville coke?

Mr. Kennedy: I think possibly if a furnace was going to use Pocahontas coke, it would be wise to make the furnace ten or fifteen feet shorter, but it is probable when the Connellsville coke gives out there will be a large increase in by-product coke which is even stronger than Connellsville coke, so far as crushing strength goes.

Mr. Muellenhoff: What is the length of time of a charge going through the whole furnace, from the time it is charged until it comes out as iron and slag?

Mr. Kennedy: I could not tell very well without figuring up the amount that is in the furnace at a time. I suppose it runs 12 to 15 hours, maybe more and maybe less.

F. Z. Schellenberg, Member: It is surprising to hear that it takes thirteen tons of wind to make a ton of iron. That startled me when I first heart it. Is it true?

Mr. Kennedy: It takes about 6 pounds of air to burn 1 pound of coke, and if a furnace is making iron with a pound of coke to a pound of iron, about six tons of air would be required per ton of product.

A Member: Is not the hanging sometimes caused by

the material sticking to the sides of the furnace without arching?

Mr. Kennedy: Sometimes material will stick to the sides of the furnace, but that is not very usual. As a general rule an arch in a furnace hangs a while and then breaks and comes down, and it is not usual to get what is called a scaffold—a lump hanging on to the sides of the furnace, though this sometimes happens.

[Before the Structural Section, November 27, 1906. R. A. Cummings, Chairman.]

MODERN SHOP PRACTICE FROM AN INSPECTOR'S STANDPOINT.

BY D. W. M'NAUGHER,

Member Engineers' Society of Western Pennsylvania.

The methods employed and the character of the work turned out by the modern bridge shop are the result of years of experiment and study by men of technical and practical training.

Years ago our bridges were wooden structures, framed on the ground by the bridge carpenter, but when the production and cost of iron reached a point which admitted its use on a large scale for structures requiring greater strength and durability, a demand for shops equipped for fabricating this class of work was created.

The advent and development of the manufacture of steel, the enormous increase of railway traffic requiring greater weights in locomotives and rolling stock, the building of our modern fireproof buildings, and other structures which absorb such a large percentage of the steel output, has created such a demand that special shops constructed, equipped, and operated to fabricate steel structures on the most economical lines became a necessity. The object of this paper, however, is not to describe the modern shop but to call attention to some things in shop practice which are still open to criticism.

The first operations in the shop are the making of templates and laying out of the material for punching, drilling and shearing. The correctness of these operations not only depends on careful manipulation, but primarily on accurate and clear detail shop drawings.

These are often made with too many notes and details on one sheet. These may be clear to the draughtsman, but are confusing to the shops and inspectors. I have in mind two sheets, each of which covered four columns. The notes were so numerous that it was necessary to build up each column complete and lay out the parts affected by the notes separately.

A uniform system of giving important dimensions would save time to the shops, and the inspector. Governing distances such as the location of brackets and other important connections from one end of the member should be given. These are often omitted, making it necessary for the shop men and inspectors to foot up a lot of intermediate spacings having no relation with a governing distance, In many cases we find the sum of a lot of short spacings on the punched work will not agree in the aggregate with a fixed total.

Where separate governing distances are given from one end of the member to each group of holes, bracket or connection, the work can be laid out and checked quickly by reading these distances at a glance.

Distances are often given from the intersection of lines on the drawing where the intersections fall outside of the member without giving the distance from the intersection to some point located on the member itself. This necessitates a full-sized layout of the part affected, or the construction of some means outside the member from which a distance can be measured. Beams connecting to brackets on members which come at an angle, are not so easy of access on the member as they are on the drawing board, and while it is necessary to show the angle or bevel on the drawing, it is also possible to give certain dimensions to locate the connection without the necessity of the shops and inspectors making full-size details to locate them.

Ends and sections of members should all be made under or above the same view. The practice of showing ends and several sections of the member under different views, confuses the relations between them, and necessitates turning the drawing over or having the member placed in different positions in

order that the relations of connections may be carefully checked.

Where members are opposite hand this practice is especially valuable, as it enables the shops or the inspector to compare the relation of all connections readily.

Splice plates connecting members which are milled are often punched before matching the members, with the result that the space covering the splice is always greater on the plates than the sum of the distance of each on the two members. This is due to the fact that the sum of the intermediate spacings, the end spaces of which affect the splices, are always less on account of punching than the fixed length of member.

The practice of only punching one end of splice plates and leaving the other end blank until members are joined, insures good holes in both.

One of the banes of an inspector's existence is the failure of shops to make stiffener angles to bear between the flanges of girders, against shelf angles for beam seats, and in similar situations. Specifications are usually clear on this point, and when his attention is called to it no shop foreman denies the fact that stiffener angles should have a close fit, unless expressly shown otherwise; and yet it is one of the most common sources of trouble and annoyance. This is one of the examples where a miss can be as good as a mile. A stiffener that does not bear may mean the failure of some part of the detail to bring it into a bearing. Every employee handling such parts should know the importance of this point.

Filler plates, while they are generally no more than the term indicates, should fit in the space that they are intended to fill. They ought to be long enough so as to leave only small spaces at the ends that can be filled with paint. In some instances it is required that they be a close fit. They should then touch the angles or other parts at ends. Where a bearing fit is demanded it is essential that the fillers fit snugly, as the case is one requiring assistance from the fillers in carrying the load.

How many shops do we find adhering strictly to the letter or spirit of specifications as regards cleaning and painting.

Many a first class job in the shops is passed over to a gang of cheap foreign labor to be cleaned, painted and loaded on cars for shipment without any regard to how the painting has been done or even to its appearance. Without taking account of the kind of paint specified, I submit that no painting can be properly done unless the surface of the material is properly prepared to receive it, and no paint can be properly applied by compressed air or whitewash brushes as they are commonly used. Paint should be rubbed in, not daubed on.

The weighing out of finished members is another item in our bill of particulars that calls for attention on the part of some shops.

A shop which cannot weigh out its finished work is not a complete shop.

The practice of shipping on estimated weights is a bone of contention, and is many times the cause of litigation or adjustment. With the correct actual weights given there is no ground for argument. The shop is getting all to which it is entitled, and the buyer knows what he is paying for.

With all the improvements in the machinery and appliances used in our modern shops, the human element enters largely into the character of the work executed. To unskilled labor is largely due many of the mistakes and troubles which we constantly meet in our inspections at various shops.

Every shop aims at turning out first class work, and all modern shops have been equipped with tools and appliances specially designed for the fabrication of structural work not only on the most economical lines, but also by most approved methods. With the constantly increasing demands for finished tonnage comes a greater demand for skilled labor. Without a full complement of skilled mechanics in all departments the efforts of the management to secure the best results will prove abortive.

DISCUSSION.

The Chairman: Gentlemen, you have heard the paper and it is on a subject that is very opportune, and we are very fortunate in having with us this evening a good many eminent members who are identified with the structural steel business, and we will therefore expect to hear very lively discussion. Mr. Gerber, may we hear from you?

Emil Gerber, Member: I notice Mr. McNaugher made a very strong point of the stiffeners fitting. It is not a very difficult thing to make the stiffeners fit right on the top and bottom in the ordinary plate girder construction. It is sometimes very difficult to fit them for the entire width of the flange and also fit the filler at the root of the angles. I am sorry Mr. McNaugher is not here so he could explain just how he wants them to fit. It may be pertinent to ask, what is the object of the stiffeners? It is evidently to keep the web plate in shape. I have heard very prominent engineers, not in the manufacturing line, express their opinion that if they had the moral courage they would cut the stiffeners on a bevel and make them true stiffeners of the web. If it is a stiffener only, why should it bear on the top and bottom, and why the necessity for a fit on the fillet and flange when it is not intended to stiffen anything but the web? It is not so difficult to make stiffeners fit reasonably well on the horizontal flange or the fillet of angle, but it is not easy to make them fit both at the same time, and it is of no consequence whatever that they fit the fillet because the fillet is strong enough in itself to take care of itself.

Mr. McNaugher also says that the fillers should fit so close to the angles that paint will fill the spaces. The commercial angle is not always as wide as the nominal width. A 6 x 6 angle may run from 6″ to 6¼″ in a length of 30′ to 40′, and in order to make all the fillers fit close to the hanger it is necessary that each filler should be fitted for its place after the angle is put in place. That, of course, is possible, but it is not commercially practicable. And, for that matter, I do not see

that there is any necessity for that kind of a fit. Besides, fillers are sheared to length, and it is impossible to fit the rounded edge of the angle. In practice, we frequently measure the width of heavy angles for any given structure and then cut our fillers to fit as close as possible without machining. In the entire matter of structural designing, the necessity of clearance is understood thoroughly by the shop man who is up against that every day. And you will find the detailer is very anxious to make plenty of clearance, not only for the shop, but for the purpose of having the work go together well after it gets into the field.

In the matter of painting, I have been somewhat of a paint crank myself for a good many years, but about the last time I spoke about paint at an engineers' meeting, a friend of mine, a prominent western engineer, said: "Don't talk paint any more, as it is only a minor matter anyhow." And he was quite right. I do not think the purchaser should try to get his material painted to perfection in a bridge shop. It is not the proper place; the conditions are not right and the vicissitudes of the material after it leaves the shop are such that all that should be done in the shop is to get a coat of paint which will protect the material until it is erected. When the material is erected, it is time to investigate it, scrape it clean and put on paint so that it will not be knocked off by any future handling. And my own opinion is that the best thing you can put on to structural work in the shop is pure linseed oil without the admixture of anything else whatsoever. The shop coat should be a temporary covering only; the actual painting should be done after erecting. And that temporary coating should be of such nature that you can see what you have after it is erected. If your material is somewhat rusty and you have simply a coat of oil on it, you can see after it is erected just where you should scrape and where you do not need to scrape; whereas if you put on a coat of paint the chances are the painter in the field will not scrape where he ought to. Then if there is any slight coating of rust on the material, the oil is likely to penetrate it and the scale, and after it has been on a

little while, the scale comes off much easier than if it had not the coat of oil. And in line with that, the first coat of paint, whether in the shop or the field, should be comparatively thin. We have specifications which call for 33 or 34 pounds of red lead to the gallon of oil. You might as well put on putty because the mixture is so thick that it will not adhere to the material as it should.

Richard Khuen, Jr., Member: I might indorse what Mr. McNaugher says about shop drawings. The tendency to-day is to crowd on a sheet as much as possible and get the work done as cheaply as possible. And then they attempt to cover their deficiency in that respect by an abundance of notes and that is certainly bad practice. The extra money you spend on tracing paper and detailing; detailing is very slight indeed; is more than made up for by the decreased shop cost due to clear drawings. And by clear drawings I mean not only the detail spacing but the main dimension figures, what we call inspectors' dimensions, so that the inspector can locate the various points of a structure, like brackets, as was referred to, off hand. Of course that increases the cost somewhat of detailing but it gives the man who checks up the work in the shop something to check from and it never will make it necessary for the inspector to add up a lot of detail dimensions in order to check the position of any part of the member. Where you have in a member entering another the outside dimensions of the entering member should be clearly given and should be marked "Must not over-run," and the inside dimensions of the entered member should be given and marked "Must not underrun." So that when the work is assembled in the field it will be sure to fit and not make it necessary to spread one member in order to get the other one in. The slight additional cost there may be in the drawing will be amply made up elsewhere.

Edward Godfrey, Member: I do not agree with what one of the former speakers says with regard to the use and importance of stiffeners. The end stiffeners particularly in girder spans are not merely to stiffen the web but to take the full reaction of the girder. If we did not have the stiffener

there the whole reaction of the girder would be taken by probably half a dozen rivets which come immediately above the bearing plate. Then again stiffeners under beam seats are not to stiffen any web because they are not on a web in many cases. They are to take the load and it is absolutely essential if we have the structure of proper strength that those stiffeners bear against the shelf angle, because the load is carried directly from the shelf angle into the stiffener; and if the stiffener be cut off or beveled you would have just a few rivets coming in the shelf angle to take the full load of that beam unless you depend on something failing and then the load on the shelf coming on the stiffener.

Then in the matter of shop painting there are many parts of the member that cannot be painted again in the field. They may be riveted together or put together in such shape that it is impossible to get at them to paint them again, so that the only paint they receive is what they receive in the shop, which is very often inefficient.

W. L. Shaw, Member: What Mr. Godfrey said in regard to end stiffeners is true. But there is another point to be considered. It is not always optional with inspectors what they shall accept. They have specifications to follow. I have in mind a contract for 50,000 tons of work in which the engineer was not particular at all whether the intermediate stiffeners were close at the top so that they bore on the bottom chord angles, and he insisted on the end stiffeners bearing on both top and bottom.

Mr. Gerber is right in what he says that all angles are not rolled uniform. But it is impossible to have all stiffeners take a bearing on the outstanding flange of the angle. I think that it was Mr. McNaugher's idea that where stiffeners are specified to carry loads, such as beams under brackets, they should fit up close. It is common practice with some shops to mill all stiffeners, while other shops simply shear them. With regard to shearing it is not absolutely necessary that all stiffeners should be milled in order to fit, because there are shops that shear their angles as close as it is necessary to fit.

There might be a great deal said about tights fits. I well remember when I first started inspecting that my preceptor said: "You want to remember that there are very few points of a bridge that come together, and those are the points you want to look out for and see that they are clear." Many detail drawings are made so there is no way to get the distance a certain bracket is from the end of the member, unless you foot up all the intermediate spaces. Unless the governing distances are given, locating connections, there is no check, and no telling whether that footing is correct or not.

With regard to tight fits, we all know you cannot get a six-inch pin into a six-inch hole, but there is a certain allowance that you can make and get the pin in and still have a good bearing. Such allowances are well established in modern shops.

With regard to members fitting one with another, Mr. Khuen speaks of the distances that should be given. It is very essential that an inspector should not only see that these distances are maintained, but it is well for him to compare the members as they go out of the shop. There is a vast amount of satisfaction in inspecting work to know that it is built within the requirements of the specifications, and that it will come together in the field.

Mr. Gerber: When I said stiffeners I did not mean bearing supports, as to which I agree entirely with the other two gentlemen.

Mr. Godfrey: Another thing mentioned with regard to intersections outside of the plate in which the rivet holes occur, for instance, I inspected some columns where the connections on gusset plates had their intersections inside of the column. In order to check them up it was necessary to get out all the templates and check them and to see that the holes on the columns were correctly punched according to those templates. Now it would have been a very simple thing to make all those intersections of rivets on the gusset plate itself by changing the direction a little so as to strike a rivet in place of running them inside the column, where it is absolutely impossible, on the

work itself, to measure the location of rivet holes to see if they are right. If this were drawn to the attention of the draftsman he could readily see what trouble he is causing the inspector, and how much more the risk of error is. In this particular set of columns I found a good many gusset plates up side down · the wrong bevel was at the top of the column, the one that belonged at the bottom. It could only be determined by checking from the template.

Willis Whited, Member: I think it is well, as has been said, to space field holes in diagonals of lattice girders, lateral connection plates generally, crocked connections to columns, connections on hips and valleys, etc., from points that are easily and accurately located on the finished piece; but I think the proper place to check all such things is in the template shop. In fact, drawings should be made so that the template maker and the assembler can easily and surely check up the work. It is much cheaper and better to correct mistakes while the work is in process of manufacture than after it is finished, and better still to make it right in the first place.

Lateral connection plates and similar pieces, when they are so nearly symmetrical that the assembler is liable to get them on the wrong way around should, I think, have the rivet spacings, where they connect to the main members, so made, wherever practicable, that they will not fit if assembled the wrong way around.

As to fitting of stiffeners, it is hardly ever necessary that they should have a close bearing at the ends, except under brackets and at the bottoms of the end stiffeners of plate girders, and on plate girders where there is a heavy concentrated load at the top. I think that the best way to fit them is by milling; for one reason because it gives a better bearing, and also because it tends to square up the angle against which it bears. This is especially important in the case of column brackets where the bracket angles are almost always distorted in cutting them off. As to the fitting of fillers, that is nearly always a question of appearance. However, if they are in

places where water is liable to accumulate, they should fill as well as practicable.

I like the idea of drilling the holes in at least one end of chord splices out of the solid metal. It may be some extra trouble in the shop, but it makes the field holes true, round, and the right size; thus making it much easier to get tight rivets.

Long splice plates are often troublesome things, they are so apt to get bent in handling, they are a nuisance in erection, and they are occasionally cracked slightly in straightening. It is much less expense than would appear to the inexperienced to ship them loose and rivet both ends in the field.

J. K. Lyons, Member: In regard to obtaining weights, if scale weights are wanted, use truck weights. It is not practicable to obtain the weight of each small piece separately on the scales. If the weight of each piece is required, the only feasible way of obtaining it, is by calculating it from the detail drawing. Even with the calculated weight you do not check the separate pieces against the scale, you take the truck load and apportion it. I have tried to get shop men to load only similar pieces on the truck but they have good reasons for not doing it. The material is not finished that way; you will probably get a dozen kinds of small pieces on the same truck. It would help in the billing end if you could bill by the truck load.

In regard to paint, there is no paint that amounts to much until after the steel has been exposed to the atmosphere a sufficient length of time to eliminate the mill scale; further, there is not much use spending time discussing how the paint is applied or the quality of the paint until that time has arrived. I do not think the mill scale is thoroughly off until after it has left the shop, and there is not much use in painting it until after it is erected. As soon as it is off you can paint it and you will have a paint that will probably preserve your steel a great many years. The best shop paint is a coat of linseed oil.

Curtis M. Canaday, Member: While I have never done any shop inspecting I have thought considerable swear-

ing when I got a piece I wanted to check up and found that the reference points were all in the atmosphere. Referring to the point that was specially spoken of by Mr. Godfrey, where he had a diagonal with the intersection line running clear down into the center of the column, I think draftsmen often do that with the idea that by going down to a common center they eliminate eccentricity. They forget that any way these connections are made they have eccentricity. The minute they rivet the gusset plates to connection angles on the outside face of the column, eccentricity is introduced and is measured by the actual distance of the rivets from the center line of the column.

With reference to the stiffeners, as a matter of course, Mr. Gerber is correct in saying stiffeners do not need to be tight fitting. Of course, if stiffeners are to act as columns or posts in supporting concentrated loads, as they do in crane girders possibly, or other girders with concentrated loads coming on stiffeners through flange or seat angles, it is necessary that they should fit tight. But for intermediate stiffeners in girders, there is no structural reason why they should bear against the flanges.

In the matter of painting, from the inspector's standpoint, oil would be about the best thing that could be applied in the shop, aside from the surfaces which come in contact, which have to be *painted*, of course. Imperfections show up, more clearly under a coat of oil than if they are covered up entirely under a coat of paint. Then from the erector's standpoint, the "Hunkey" very often in painting covers the marks in a way that is sometimes a pretty serious thing to the erector, and I have found to my sorrow, in the field, that these marks are obliterated more often than one would imagine.

Mr. Shaw: In regard to the question of weight, it is quite a hardship to ask a bridge company to put a lateral on a truck and then go back and get another one or a cord pin, where the work is being paid for by the pound so that it is necessary that the weights should be checked in a measure to see that they are right. For small material, such as would take several

members to make up a truck load, I can see no objections to that system being carried out, provided in the invoice it is stated just what members are on the truck. I have in mind an incident which occurred where I was required to give the comparative weights. It was city work. I noticed on the invoice part of it was marked "One Barrel of Traps." I asked the man what was in the barrels and was informed it contained chord pins and one thing or another. It was pretty hard for an inspector to figure out comparative weights from anything of that kind. It is possible if two or three kinds of small members are put on one load to take the corresponding weights and compare. It saves the bridge company from running back and forth with a half load on the truck; thereby adding to the cost. Another instance occurs to me in which the contractor was the loser. I was expected to get comparative weights on a lot of columns, a very large order for the New York Elevated. They ran out two or three columns on a truck and when I had figured the corresponding weights I found they were all light. I asked the shop superintendent to run them out separately. This he refused, but said he would run them back over the scales the same way he ran them out. I said that would do no good for they were running light. The next day when I came back the scales were torn up and adjusted, and the weights were correct.

Mr. Lyons: In regard to stiffeners bearing, I do not remember that I ever saw a specification which did not have a clause referring to them. I think much of the contention between inspectors and bridge shops is due to that old tradition in the specifications requiring an additional factor of safety in something they were not sure of in the early days. The stresses were not always as easily determined as they are to-day. The theory of stresses was not understood as we understand it. There is now no difference of opinion between inspectors and shops as to the point where stiffeners should bear; for instance, the end stiffeners in a plate girder. If specifications clearly stated, "Stiffeners will not be required to bear or have a driving fit when only acting to prevent the web

from buckling," I think about 90% of the contention would be eliminated. The real trouble is in the specifications.

A. Stucki, Member: A good deal of trouble between inspectors and manufacturers could be avoided by dimensioning, and showing the web stiffeners in such a way that anyone sees at a glance that they are not intended to bear against the chord flanges. This will relieve the inspector of the responsibility and put it, where it belongs, on the engineer. Such a clearance will also facilitate the painting at this point, will do away with any fitting and thereby obviate the much resented "bad job."

Many points are mentioned in the paper, which are really covered by good "Drawing-Room Practice" without referring especially to structural work. For instance, the rules regarding placing the different views are well defined and should be closely followed. All dimensions should be given once, but not repeated, unless in complicated designs such is necessary for the sake of clearness. This will facilitate the work in making changes on the drawings and will reduce the chances for oversight in not changing all the figures, covering the same dimension. All rows of detail figures should be complete and accompanied by an over-all dimension. Again, if for instance a gusset plate of a peculiar punching is to fit to a chord on one side and to a column on the other, it is not only necessary to locate every hole correctly, but they should be located in exactly the same manner, using the same base line, same angles, same figures, etc. This will greatly facilitate the work of the checker, template maker, and inspector.

Regarding the use of linseed oil for the first coat, it undoubtedly acts as a protection, if such steel is not exposed to the weather too long. This point, however, should not be overlooked as Linoxyn is pervious to moisture. One of the most essential points in this connection is the thorough cleaning and painting of the surfaces which are inaccessible after the parts are assembled.

K. A. Muellenhoff, Member: I believe that the bridge companies should clean the steel properly. To let it go

out and wait until the mill scale comes off makes it necessary that the structure be watched very carefully and painted several times, because the mill scale will not come off all at once. And there are means to get rid of that mill scale completely. The only way to have an effective protection is to pickle the steel before it is painted in dilute acid, then put it in lime water and then in hot water and you can paint it and be sure your paint will stick. This is the practice as far as I know on all European railroads. First a coat of linseed oil with 10% zinc white. Then the pieces are stored until the inspector has done his work. Then comes two coats in the shop of linseed oil and lead and then another in the field and then at last the finishing coat. There we never have the trouble that steel rusts so quickly.

If stiffeners are not required to fit, for example intermediate stiffeners, I think it would be the best thing to cut them on the skew. If it is cut off square ⅛-inch or ¼-inch there will be a place for dust to collect, and as has been pointed out in former meetings places where dust can collect are found more exposed to rusting.

The testing of rivets has not been mentioned here. I would call attention to a test that seems not to be as well known as it deserves, on acount of the time you can save by it. It is not necessary to test each single rivet with a heavy hammer to see that it is tight. A very effective test is taking a very light hammer and running it rapidly down the whole line, you will quickly learn to hear the sound of a loose rivet: there is a different sound. I had occasion once to test a number of tanks that had to be absolutely tight. We found out all the rivets that were not tight in this way and never had any trouble afterwards.

Mr. Shaw: I agree with the speaker in regard to this method of testing for loose rivets and a hammer of that kind will always stick to a loose rivet and rebound from a tight one. And it does not take long for an inexperienced person to learn to tell by that method.

J. A. McEwen, Member: There is one thing about clearance that can be taken care of to some extent, and that is by giving center lines, as at the ends of beams, girders, etc. If there is a center line or something to show the nature of the connection the shop will know just how to treat that. In regard to fitting up stiffeners I think there are a good many tricks that shop men are on to that let them out of difficulties. Shop men can make stiffeners tight if they are sheared reasonably close at all by fitting up the girder and leaving the top chord angles off until the stiffeners are in place and then putting on the topchord angles. Of course, the holes may not match exactly, but a good fit can be obtained without any unnecessary expense.

Then the question of general dimensions on drawings is important and something which detailers when they first commence do not realize. I think a detailer should be instructed that the first thing he puts in should be some general dimensions so that every man down through the shop would have something to work to. A few explanations to detailers will avoid a lot of these things. Of course there are some things which are done for appearance only. I think there ought to be a happy medium between necessities and appearances, for example where diagonal angles come up against a chord angle.

I noticed some one made a remark about having things shown a certain way, and the inspector is required to follow the drawing. I know of one case where a lot of lattice girders had the diagonal shown fitted up without any clearance where they met the chord angle. The shop man complained about this and he said the inspector was bound to have it come that way as shown. So things ought to be shown the way they are intended to come. A little explanation and general instruction in the drafting room will avoid a lot of these difficulties.

[Before the Chemical Section, December 20, 1906. Chas. H. Rich, Chairman.]

THE INDUSTRIAL OUTLOOK FOR PHYSICAL CHEMISTRY.

* BY ALFRED SANG,
Non-Member.

In plain, every-day English, the word *definition* conveys some definite meaning which satisfies a query; the *rhetorical* definitions which satisfy us in every day life are, however, quite unsatisfactory to the philosopher; he is always seeking *logical* definitions, and, while he may be successful when dealing with the concrete, he fails when he attempts to define the abstract data upon which he rests his belief in the concrete; his failure is due to the lack of a higher term of comparison which is just as essential to a definition as is the lower term.

Definitions of abstract scientific terms are continually shifting and broadening, and we find one definition overlapping another; we then hasten to coin new words which, while they are useful as *working* descriptions, only serve to make confusion worse confounded for the general public.

A definition is always limited *ad infinitum* by at least one other definition. Thus, when we say that Force is a mode of Motion, we create a convenient axiom, and we are able to prove that it is sound and legitimate as long as we do not attempt to define Motion. If we succeed in defining Motion we find that Space is still undefined. How glibly scientists impose their axiomatic definitions on the world! They rearrange them from time to time to accord with new knowledge, and lay them down—or set them up—as dogmas which are to be strictly accepted, although subject to change without notice. The definitions of Physics as given in most textbooks illustrate, better than do those of any other science, the

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truth of Montaigne's aphorism that "nothing is so firmly believed as what we least know," and the depth of our ignorance is often the gauge of our conceit.

But, if the definitions of the terms of science are unsatisfactory to the logician, how much more so are the definitions of the sciences themselves. Science is one, and when we view it as a whole we can readily see the difference between its various branches, but we cannot discover any distinct boundaries for the very good reason that there are none. Were I to give you a definition of Physical-Chemistry it might serve tolerably well for a few years to come, but it would ultimately become hopelessly inadequate.

When the physicist is found poaching on chemical preserves he calls his act "molecular-physics"; when, on the other hand, the chemist is caught on physical grounds he calls it "stereochemistry." The origin of chemistry is lost in the past; she may have some dim recollections of temples and incantations, but her past is practically blank until we find her enslaved by visionary alchemists. Her release came with what we call the dawn of chemistry and thanks to a liberal and systematic education, which developed in her the faculty of introspection, she discovered how wonderfully she was made; the Atomic Theory became an essential part of chemistry. It was many years, however, until chemistry dared look "behind the veil" and she was barely saved from becoming a dessicated old maid by her timely wedding to the science of Physics; the desire for companionship was mutual, and to bring this short parallel up to date I must add that the happy couple resides in the Science Apartments which are built, as you know, of the best brand of Philosophy and erected on foundations of Truth. Dame Mathematics is the housekeeper of the Science Apartments and she is such a faithful old soul, and so indispensable, that all the tenants willingly put up with her very precise manners and her oftentimes tiresome conversation.

Physical-Chemistry, as you see, is not a self-contained and readily defined science; it is a condition of things which

might be described as a metaphorical state of wedlock of the two great sciences of Energy and Matter: Physics and Chemistry. I say wedlock, because the children of this wonderful union we see all around us; they are known by such names as Radiology and Electro-Chemistry, each of these sub-sciences constantly creating specialists, the ultimate results of whose labors are, I fear, not sufficiently appreciated by most men of to-day.

The chemist must work with one eye on Physics if he intends to progress and to secure original results. We all feel that the synthetic power of chemistry will, in time, bring about most important results. Some of us may wish that chemistry would teach physiology how to reduce our hours for sleep from eight to four, or less; this could only be done by building up artificially what is now being done by so-called natural means; it would be a synthetic process. Others may wish that a diet be discovered which would make one meal do the work of three so as to give them time, possibly, to discover how to do away with all the other pleasures of life. However this may be, it is certain that the synthetic power of chemistry depends on the development of physical science and the control of forces. Reactions which are readily brought about by simple means such as solution, the application of a moderate heat, sometimes even by mere contact, cover a wide range in analytical work. Synthetical work demands, as a general thing, powerful dynamical conditions which are discovered by and applied through physical science, because the unceasing endeavor of Physics is to fathom and to reproduce the mighty efforts which attended the creation of matter and the neucleating of this planet from the nebular mist.

What may we not hope from synthetical science when, placing ourselves in imagination in pre-organic times, we contemplate Man as he now is! Man, *created by synthesis* and by systematic evolution within a conceivable period of time! Man, who in the arrogance of his mental powers dares to deny the possibility of a greater Mind than his own!

Chemistry, therefore, through its fecundation by Physics, as one of the past presidents of the American Chemical Society has so fitly expressed it, gains in synthetic power; progress is attained by building up, by creating; analysis is a factor of progress only in so far as it helps that building up. The analysis of matter bears about the same relation to its synthesis as the reading of a poem does to its creation. Almost any man of average intelligence may be taught to read and appreciate Hamlet or Faust, but it took genius to write them. Analysis converges to a center, synthesis diverges and expands to infinity; the analyst may help to find the angle of divergence but he cannot reach out.

It is worth noticing that it is for the most part in Inorganic research that the fundamental laws of the Universe have been partly uncovered. This community is, very naturally, far more interested in inorganic than in organic work, notwithstanding that organic chemistry centers around Carbon, which is so lavishly supplied to us by our manufacturers, who seem to consider it a civic duty to sacrifice part of their fuel fo enable us to see what we are breathing, and incidentally giving us black-lung, or anthracosis, as the doctors call it. It may be, on the other hand, that dollar-worship excludes formula-worship. After all, I think that we are to be congratulated on our faith in inorganic work, for therein lies the industrial power of the future. Organic work is of course indispensable to our health and happiness, but carried to excess, as it often is, it creates a mania for seriating and discovering intermediate compounds, and when a man gets the mania of chemical permutations it seems to paralyze his powers for useful research. The practical chemist works systematically *with an object in view*; the formula-worshipper works no less systematically but without an object—unless we consider it a worthy object to enrich the statistics of the science; he is like unto an astronomer who would devote all of his time to increasing the number of known planetoids; he is of far less use than the man who hunts for the North Pole. The seriating of compounds may have its value, because value, like everything

else, is relative, but I cannot help thinking that the new compounds would be discovered by the practical chemist when the time was ripe for their discovery; when they were wanted. The practical chemist has a utilitarian plan of research; his discoveries are products of evolution, even in cases which at first sight appear to be accidental. Most of the new organic freaks which choke the pages of our chemical periodicals are prematurely born.

And yet, organic chemistry is in many respects of more importance to humanity, as such, than is inorganic chemistry. I am not criticising organic chemistry, but I *am* criticising that class of over-specialized research-fiends which is making the outlook for German science less hopeful than most people are wont to suppose, and than the admirable work of the German pioneers of organic science had promised. I do not claim originality for this opinion; as far back as 1898, a German scientist, Dr. Ferdinand Fisher, expressed a similar one. It is during times of prosperity that we first discover the seeds of decay and it is therefore during times of prosperity that we must be watchful and destroy these seeds before they take root. A French writer recently comparing French with German science, likened the first to an army of generals without soldiers, and the latter to an army of common soldiers commanded by sergeants and corporals. I think that this estimate is correct. In English-speaking countries, on the other hand, science has generals to do the bulk of the thinking and soldiers to do the bulk of the work, until such time, which I trust may never come, when the levelling influence of so-called Socialism may have levelled everything down to mediocrity, so that we shall have a state of equilibrium between thinking and working which will produce no light, unless it be the phosphorescence of decay. Such times shall never be; the genius of the race is against it. The force which impels progress is like a circulating flow between higher and lower levels of intelligence and the leaders of men who despise those whom they lead, despise those to whom they owe their positions as leaders!

Let me express my belief that, notwithstanding the pessimism of most of my contemporaries, Anglo-American science, well generaled as it is, and with material in the ranks which no race on earth can surpass, has nothing to fear in the long run from Teuton or Latin competition, if it but holds its present course.

Organic Chemistry, whose great curse, formula-worship, I have just touched upon, furnishes a very fine example of the value of well-organized synthetic research. I refer to the industry of the coal-tar derivatives, which, while it has firmly imprinted the name of William Perkin on the tablets of history, will always be more particularly remembered as the work of German scientists, who have developed and maintained it by their peculiarly German qualities of Penetration, Perseverance and System. I hope the day will come when American coke interests will show a little more active concern in stemming the growing tide of coal-tar product importations from Germany, and incidentally in reaping a legitimate and untainted profit from the smoke which at present taints the atmosphere of Connellsville and other localities. Industrial aim is what differentiates inorganic from organic work. The two do not readily mix, any more than the manufacture of pig iron and hosiery can be conveniently carried out under the same roof and by the same management.

We must not forget that organic chemistry as applied in the sciences depending from Physiology, has been steadily lengthening our span of life; what more than this could it do to claim our respect? Having now made my peace with both German science and organic chemistry, I shall return to inorganic chemistry, which is at present—though it may not be always—of more immediate interest in the discussion of Physical-Chemistry and its industrial possibilities. Professor Loeb has recently given us "The Dynamics of Living Matter" but, as one of his reviewers writes: "Physical Chemistry in relation to inorganic material is in a state of flux, one theory displacing others with startling rapidity. It is, therefore, a little early to apply it to organic and living substances with

any hope of obtaining universal acceptance of the theories put forward."

It can hardly be contested that inorganic chemistry has made more rapid and especially more definite progress than organic chemistry. As a system it is more complete; as an instrument in the hands of the technologist it is more powerful. This is no doubt due in a great measure to the absence of the problems of life and growth; but even now organic chemistry is appealing to Physics for help to explain these problems, which so greatly complicate its work; and furthermore, do we not find Physics discovering new mines of research in the growth of crystals and Chemistry detecting what seems to one or two ambitious minds, as almost the vitalizing effects of radium salts upon certain colloids? Have we not also heard of the fertilizing of certain marine eggs by increasing the proportion of our inorganic friend, sodium chloride, in sea-water? And is not the non-actinic milk bottle to take the place of formaldehyde? It looks almost as though at some future time the name *Organic* Chemistry might become a misnomer, because while it is true that certain carbon compounds are, to the best of our knowledge, the only supporters of life, under terrestrial conditions, it remains yet to be disproved that they owe the origin of the sustaining power of their vital activity to inorganic reactions which supply that complexity of energies we call Life.

From the day that Dalton re-discovered the atom, chemistry has been under the influence of Physics. From a mere influence it has become an inter-dependence which has resulted in discoveries piling up on discoveries until a man is no longer up-to-date unless he keeps in touch with the transactions of every learned society in the world. Physics has become the most powerful instrument of research in Chemistry and Chemistry is the most important adjunct to every instrument of the physicist. When Van't Hoff made his memorable researches on solution and osmosis, he was doing the work of both the chemist and the physicist; and what can be more typical of this combination of the two sciences than Radiology?

There are many indications that delicate physical methods will in time replace purely mechanical manipulations in the work of the chemist. In many quarters chemists are lightening their qualitative work by rapid blow-pipe tests, and color-tests are used in the laboratories of every steel mill; but what is this compared with the promises of spectrum analysis? The day may come when for a qualitative test the chemist will merely place the substance to be analyzed in a diminutive electric furnace, apply his eye to a spectroscope, manipulate a few absorption screens, and find his answer in a printed table. To understand the power of the spectroscope—whose analytical power, by the way, was discovered by the *chemists*, Bunsen and Kirchhoff—you have but to realize that by its means we can calculate the motion of a star *in the line of sight*; that we can discover and measure, with a most astonishing degree of accuracy, motions which are taking place at distances which stagger the imagination; through the influence of this motion on minute and immaterial waves of light, propagated at a speed of over 180,000 miles a second. We may even hope that the spectroscope in conjunction with the magnet, the electroscope and other physical instruments may some day furnish us *quantitative* answers just as the tachometer instantly gives the speed of the revolving shaft to which it is applied.

In so-called chemical methods of analysis, the human element is too much in evidence, there are too many chances of error. With optical and electrical instruments the chances of error are reduced to a minimum on account of the comparative ease with which these instruments are standardized, their results being practically constant thereafter. We cannot use chemical reagents over and over again after they have been standardized; these reagents are partly converted into the result, and we must, with care and loss of time, prepare new reagents and standardize them. How is the most delicate operation of weighing performed? Electrically! If the mass of a particle one thousandth the mass of a Hydrogen atom, and moving at a speed approximating that of light,

can be computed with tolerable accuracy, why should we not look forward to the time when masses of matter will be weighed by means of some electrical manifestation of their intrinsic mass-energy?

I have already mentioned the use to which waves of force can be put to measure motion at a distance. The lengthening and shortening of sound or light waves by the motion of the source is, in theory at least, a very natural and simple means for measuring that motion. The variation of pitch supplies ample information if we only design the proper means for reading it. Fizeau wrote more than forty years ago: "A ray of light with its series of extremely minute but perfectly uniform waves, may be regarded as a natural micrometer of the greatest perfection, specially suited for measuring lengths." By taking advantage of the interference phenomena of these tiny ripples of the ether, we posses a vernier-gauge which no human agency can destroy, as eternally accurate as the ether itself, and in no need of certification by any Bureau of Standards.

The measurement of high temperatures by thermo-electric couples is now in universal use, but when we consider the sensitiveness of the gold-foil electroscope we can readily look forward to the electrical measurement of variations which are at present beyond the range of our most delicate galvanometers. We find that as a general thing there are several avenues of enquiry open to the scientist whose work lies in the direction of developing what I might call physical metrology; thus, the principle involved in the variations of rotary polarization which have been found to accompany changes of temperature in quartz and other minerals may yield results even more sensitive and more practical than the electric pyrometer.

I do not think that physical methods can, for many years, replace chemical methods when matter is to be handled in masses, but I do think that the industrial testing laboratory of to-morrow will use mostly physical apparatus in carrying out tests. If there is any truth in this, it means that students of chemistry must not only take a livelier interest in physics,

but must also improve their knowledge of advanced mathematics, as without mathematics physics is worthless as an instrument of research. This suggests a few words about the relation which chemists in active life should bear to the education of the chemists of the future.

In the first place, it should be impressed upon the student of chemistry that the word Chemistry comes from the name of an old Egyptian god, Khem, who symbolized generation and productiveness. If the student does not make up his mind from the very start that the most essential part of his work is to produce or help produce original results, he will not stand much chance of advancing very far beyond the wash-bottle and the crucible-tongs. When I speak of students of chemistry, I do not mean young men who go to colleges. I have in mind more particularly that sympathetic lot of young men who dissolve steel turnings, filter, wash and weigh up day after day in the laboratories of Pittsburgh, and elsewhere, for a moderate salary. For those who apply themselves privately to improve their knowledge of physical-chemistry I see a bright and profitable future and I think it is the duty of those who employ them and of chemical societies to help them. The advantages of a college education are nowadays counterbalanced by its disadvantages. As the late Professor Rowland once pointed out, it is the faculty and the students, and not the buildings and the income which make a university. Any man of good will can have his own private little university at home if he enjoys the friendly encouragement and assistance of those who have already "got there."

Chemists and chemical societies have another duty in regard to education. They should take an active interest in the text books which are being used in schools, for it is during the high school period that a boy can best develop a bent for scientific enquiry. To be successful in scientific work a student must be an enthusiast; he must thirst for new discoveries, even if he never makes any. Many elementary text books are not only chronically behind the times, but they are filled with references that belong to more advanced courses.

The professors themselves need the co-operation of industrial chemists; with some prominent exceptions, they do not have sufficient opportunities for investigating the advancing needs of industry. I have looked through text books used in schools both here and in England and I have been struck with the lack of graphical illustrations of mathematical methods; I have also been impressed with something so entirely at variance with my own experience that I think it worth mentioning. I have always found that I could readily understand a difficult calculation if I had some kind of solid mental picture, however dim, to act as a guide in "catching on" during the development of the mathematical process. These mental pictures cannot be formed from the school text-books of science which I have seen; they can only be formed by teaching science at first *without* mathematics, in a general popular way, which will arouse the interest of the boy. If you show a boy the beauty of what lies beyond—through a telescope, as it were—he will follow you without difficulty through abstruse mazes of figures, because he will have an object in view which he understands and appreciates. There is a further argument in favor of teaching a subject first in a general and popular way, for when later the study is taken up in a methodical and scientific manner, analogies and concordances will every now and then occur to the student's mind which will throw light on the subject and encourage him to renewed effort. If a man indulges in miscellaneous reading *after* he has left school or college, he is always in danger of acquiring a smattering which is the father of conceit and the grandfather of inefficiency. I repeat, therefore, that it behooves chemical societies to take an active interest in the teaching of chemistry if they wish their science, in conjunction with physics, to become what it should be: the most powerful factor of progress in the world.

As a guarantee of success, the physical-chemist possesses a great many rare qualities. To be successful he must love his work and he must be ever guided by truth. What better foundation can there be for character? He must be systematic

in his work and must not act with undue haste. What better training can he have to become a successful man of business? He is continually bringing, as Huxley has said, his mind in contact with fact, and the suspension of judgment which he is bound to exercise until the fact is reached, helps to develop in him a normal unbiased mentality, and his insistence on proper and sufficient evidence develops the sense of justice which makes him a good citizen of the world. As a student of the harmonies of the universe he deplores war, and while he is proud of his own country, he appreciates the rights of men from other lands to be proud of theirs, because chemical reactions are the same the world over, and chemical formulae and equations are the universal language of chemistry.

Physical chemists are accumulating knowledge which will enable industry to meet the economies in processes of manufacture which growing competition is forcing. Their work has hardly begun, but the day is coming when the "chemist who knows" will command his own price. There are many industries, the managers of which will have to be displaced because they are not chemists. These men are in a way akin to those whom we all occasionally come across, who set themselves up as authorities in matters chemical, who develop mighty inventions and remarkable products which are to revolutionize industry; these men are worse than the alchemists of old; the alchemists were, at least, in harmony with their surroundings. The alchemist of the new type who, devoid of even the most elementary knowledge, searches hap-hazard after results which will bring him fortune, is of little value to himself and still less so to the world at large; he usually destroys capital and its legitimate offspring in the form of generations of dividends. All such men as these must go. In their stead executives will be needed who have time and ability to outline research work, for no chemical industry which is stationary can endure. Freed from detail the chemical executive will work half the time with his feet on his desk and his eyes closed, a thing he does not do now because he has not yet found himself. There is hardly a prominent manufac-

turer, nowadays, who has not got over the notion that, to get results, nerve is more valuable than knowledge; hardly one who does not appreciate that chemists in their quiet, unassuming way are increasing the yield of their factories and are saving lives and money by drawing up specifications and testing materials. His life and his money; what more does the modern man of business care about? Chemists should follow the example of the engineers who are everywhere getting to be the executives of mechanical industries. Divested of the worry and narrowing influence of detail work, a chemist, as manager of a business in which chemical reactions are determining elements, is best able to discern the road to progress.

Industry has now advanced so far that the "rule of thumb" is as absurd and out of date as the powdered wig of our forefathers. Science is now recognized as the life of industry; without science, industry is a limp, lifeless body; a corpse. Invention is often called applied science. This depends a good deal on circumstances; often it is merely applied accident, and the present state of China is a conspicuous example of the difference between scientific and fortuitous invention. China discovered many things that the western world knew nothing about until many centuries later. It illustrates the old fable of the hare and the tortoise, and is a further vindication of the scientific as against the scholastic incubation of progress.

But there is an important factor to consider in the development of science for utilitarian purposes, and that is the attitude of the business men as we find them today in the height of their power. Do these men who take money and themselves so seriously, realize the latent power of the practical scientists? Some do; a minority. Happily this minority is to be found in the councils of the mighty. But should I say "happily"? Is it a good thing that such an important fact should be known to the mighty that they may be further exalted, and that the present process of social segregation should continue? I am not here to discuss such a delicate question of sociology, but having been granted the freedom of my opinions, I shall say that it is not good; that the fact that the

importance of science in manufacturing is only recognized in a practical way by the large corporations, by large and already prosperous interests, is a misfortune. Chemists may aspire to the highest positions in the industrial world. Chemists are made of the right "stuff." They analyze all right, but it is on account of their being high in mental phosphorus that they are cold-short on ambition; they should take more trouble to encourage an appreciation of their work, and therefore of themselves, among the heterogeneous manufacturers who own small and medium-sized interests, which would derive solid and lasting benefits from the injection of science into their methods. At present, small manufacturers call in the help of chemists when matters are hopelessly involved; they regard them as magicians and are disappointed if magic is not forthcoming. The truth is that they have called in the doctor when they should really have called in the priest or the undertaker.

Why should not chemists adopt the methods of business men themselves, and advertise by publishing more freely their results and their ideas?

This city is one of the greatest fields for the physical chemist—especially the metallurgist—and for the man who from keen analytical perception can build bold synthetical conceptions; if he can get thus far, here is the best place in the world for him to find the business men and the capital to put his ideas into practice. But, what do we find? That almost all the most important new discoveries in the field of the physical chemistry of steel, are communicated from abroad, and that what Pittsburgh excels in is not discoveries but the scale on which the discoveries of others are applied. This over-practical district should be the most propitious place on earth to crystallize and put into practice what in the first instance will present itself to the mind as wild flights of imagination. There is a thrilling sense of artificial power in picturing what appear at first as most impossible developments of present industrial methods. Some of our fancies become facts; others act telepathically—or would you say, catalytically—on the mind of fellow-dreamers; if five out of every hundred produce some

direct or indirect result it can be considered a very fair investment of our spare time; all of these fancies will help to develop in us a healthy and elastic mentality.

My reason for shifting the discussion so abruptly from business men to the use of the imagination, is this. There is nothing more attractive to the average business man, especially after he has been properly paralyzed by success, than the wildest and most impossible schemes. Were I talking to men of less than average intelligence I would be about to give dangerous if not actually dishonest advice; but, speaking as I am to an "elite" group of men, I say that you are perfectly justified in laying *your* schemes also, before these men of business of whom I speak. provided you lubricate them with a film of probability. This is being done every day by men of little or no scientific attainments and the demand for these men, your unworthy competitors, is not declining in the least. The American business man is a good loser and he loves the sport, but if he finds that *you* bring in an occasional horse where those of the other man fly off at curves and are never seen again, what will happen. Why, the other man will have to go to work and *earn* his living, you will get your just dues and the business men will get returns on their expenditure and give you additional support.

I fear that I have been dallying by the wayside, picking philosophical blackberries, some of them unripe, many of them over-ripe. I now reach a last consideration which has, to my mind, an important bearing on the outlook for the allied sciences of Physics and Chemistry; it is, the consideration in which pure science should be held by the practical chemist.

Pure science is variously described. It might be called that part of science which has no direct cash value. Love of country, of wife, of children, have no direct cash values, but they have a transcending value by inspiring and encouraging us in our applied work. Pure science is the inspiration of applied science, and makes it a pleasure and a means of self-culture. But I must also plead for pure science because the development of physical chemistry depends in a great measure on the interest which practical chemists take in it.

Pure science is not the converse of applied science; the converse of pure science is "no science"; applied science is complementary to pure science. There are yet some people who consider the study of pure science a childish waste of energy; in the same way does the revolution of an engine fly-wheel appear to be a foolish waste of energy to the fly who tries to alight on it. The origin of the term "pure science" may be due to intolerance in the other camp; the earlier scientists may have considered it a taint, instead of a consecration, to put science into practice. Nowadays pure and applied scientists cannot disregard each other's work, and thus it has come about that among the ablest of the pure scientists we find the ablest applied scientists; this means, that pracical workers must take more or less active interest in pure science if they want to attain eminence. Pure chemistry and pure physics have everything in common; together they constitute one science, whatever we may choose to call it; if we add to this a dash of applied physics and the entire field of inorganic chemistry we have the science of physical chemistry under its present-day aspect. Physical chemistry is the industrial science of the present. The most fundamental fact of industry is the transformation of energy; these transformations are more often than not dependent on chemical reactions; a chemist, therefore, who is not interested in energy and its transformations, is neither an industrial nor a physical chemist.

Pure science, by itself, is perhaps best taken care of by men—and women—who are not engaged in the application of the results and steeped in the dank atmosphere of commercialism. Pure science, is in good hands; university professors have shown themselves eminently fitted in this respect, both because of the facilities at their command for doing research work, and because teaching brings out in the teacher himself latent knowledge which is only awaiting a stimulus to become part of his conscious personality. But you must not allow these learned professors to do their work as in a world apart from yours. One of the objects of the Chemical Society is to bring your minds in contact. You already enjoy their

friendship, but you also need their counsel, and they need yours. It seems to me that some of these pure scientists have within recent years taken a very lively interest in the produce of the seeds which they have entrusted to your care; they know the harvest of benefits which your intelligent stewardship has given to humanity; but, further than this, they have entered the field of your activities as experts for industrial corporations, municipalities and others. In business, this is called *Competition*, and one way of meeting competition is to acquire any knowledge which may be giving your competitors some advantage over you. Pure science must therefore claim your attention; you must study the relations between its theories and your practice. Do not allow those who employ you, your customers—or do you call them your patients?—to go over your heads for expert advice, for it is *your* business to market the product of the university laboratories.

It requires the scientific instinct to be a physical chemist. Every chemist is not a scientist, but the instinct is almost always there, dormant somewhere, and there is no study better calculated to awaken that interest than the study of molecular physics.

In the modern research laboratory, one of the most important instruments is, as I have already stated, the spectroscope; how many practical chemists are there who own a spectroscope and appreciate its possibilities? And yet, who can deny that the spectroscope will be one of the most necessary parts of the equipment in the testing laboratory of the future? The electrolytic refining of ores is founded on principles which were known to our grandfathers, and yet how old is the industry of the electrolytic refining of ores? We cannot tell what power our children and grandchildren, not to say we ourselves, may acquire, when new discoveries will release the pent-up possibilities of some of the instruments and processes of the research laboratory of to-day.

Discovery is the mother of Necessity, and Necessity creates Industry which in turn rewards the discoverer. I see no brighter field of discovery and therefore no brighter field of reward, than that of physical chemistry.

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

PITTSBURGH SUBWAYS.

BY E. K. MORSE,*
Member.

February 19, 1907.
President S. M. Kintner in the Chair.

Any member of this Society who was born about the year 1850, blessed with only an ordinary memory, may consider himself fortunate to have been a Pittsburgher, or happy if a resident anywhere within a radius of 50 or 60 miles of the confluence of the Monongahela and Allegheny Rivers, as he, only, can fully appreciate the transformations of the past 50 years. The author clearly remembers his rides on the Pittsburgh and Cleveland stage coaches, the canal boats up the Mahoning Valley, and when no railroad connected Pittsburgh with Youngstown, up the Beaver and Mahoning Valleys. It seems only a few years ago when it took a good half day to ride out to the East End in the horse cars, make a fashionable call and return to the City. When the horse cars gave way to the cable systems, the transportation problem seemed solved. As a matter of fact the process of evolution of the passenger traffic was only begun. It was soon discovered that the cable roads were not flexible enough for extensions and that they were

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too expensive for the development of new resident sections. The introduction of electricity as a motive power met these difficulties. By means of the electric street car systems, the whole country is rapidly being connected and the inland towns, heretofore unapproachable by the steam railroad systems, are brought within quick touch of the great cities and business centers to the great mutual advantage of the city and town and country.

It is a well known fact that the greater the convenience, the greater the travel; the cheaper the rate, the greater the travel; the more attractive the cars the greater the travel. The traveling habit increases with the increase of convenience in transit. The number of journeys per head of population has increased in a generation in London from 46 to 400 journeys and in New York from 47 to 400.

The electric street car systems of this vicinity have within a few years made it possible for the poor man to have a health-giving home outside the city limits which no other system could have afforded him. In many cases the electric car even preceded the homeseeker. All of this must be commended even though it be granted that it be done for the nickel. The street car company eventually gets the nickels, but the public enjoys new and better home sites and the taxable valuations are greatly increased.

All these conditions, however, lead up to the one vexing problem, a congestion and overflow that is to-day likened unto the smaller rivulets, creeks and streams of the Allegheny and Monongahela Rivers which meet to form the Ohio and flood both the cities of Allegheny and Pittsburgh. No city in the world transacts the volume of business that Pittsburgh does in the limited space of that section below the "Hump"—composing about 210 acres and into which all the street car and steam road travel is discharged. And to aggravate matters there is only one street, Liberty Avenue, which is 80 feet wide, most of the others being 40 and 50 feet between building lines. The topographical conditions are such that the heavy teaming must pass through this district, and then too the streets are

irregular in their arrangement. Is this all? No, the population of Pittsburgh and vicinity is growing with such wonderful rapidity and even if the present system of street car travel can be so readjusted that the traveling public can be reasonably well accommodated, it will at best only be temporary.

What then are the conditions that confront us? Will we have more surface cars, elevated or underground systems?

Shall it be surface cars?

It is well known that more facilities for passenger travel from the business district of Pittsburgh to the residence districts and surrounding towns are needed in all directions. The greatest complaint comes from the East End; but the need is almost as great towards the north, west and south.

Of course, a more rapid movement of the cars is always to be desired, if it can be had with safety. But what is more needed in Pittsburgh is to have more cars so that passengers can have seats instead of straps and so that they need not wait while overcrowded cars go by. If quicker service can be had at the same time, in any way that will not add to the dangers of the streets, it would be welcome.

It would be easy to supply more cars if they could be handled down town. Every available street below Grant Street is occupied with car tracks; and cars are already being run as close together as they can be. Those streets even now are neither safe nor convenient.

The first necessity, therefore, is to relieve the crowding down town, and to provide the means of handling there enough cars to carry the passenger traffic without delay or crowding. Whether the added cars are to run on the surface of the streets, or above, or below them, the cars are needed. Since there is no more room for them on the down town loops of the surface railways, the natural way is to build elevated or underground roads.

The second thing to be desired is to carry this traffic in and out of town in the quickest possible time. And as elevated or underground roads can make much better time than

surface roads, with less danger to life and limb, this again suggests the same kind of relief.

So it seems that both of the objects sought for (relief from crowding and quick transit) can best be had by building above or below the surface.

When we inquire which is the better way for Pittsburgh —elevated or underground—it must be borne in mind that there are several peculiar conditions to be reckoned with. Elevated roads may be better for some cities, and subways for others, according to conditions. But in Pittsburgh some of the conditions cannot be changed.

1. The first fixed condition is in the narrow business district, which is cramped by nature. Practically, business is crowded into the district lying west of Grant and Tenth Streets and bounded on the north and south by the Allegheny and Monongahela Rivers. The area of this district is only 210 acres. Nature has so hemmed it in that it cannot grow towards the north, west or south; eastward the "Hump" shuts it in. It seems to be necessary for the convenience of everybody, to run all inbound cars from Pittsburgh and the surrounding country into this district. If railway lines should land their passengers on the north side of the Allegheny River, or west of the Point Bridge or south of the Monongahela River, nobody would be satisfied. Or if the East End Line should bring their passengers only to the Court House, they would satisfy nobody. So into this space of 210 acres all inbound cars must bring their passengers; and all outbound cars must pick them up. This territory is smaller in proportion to the amount of traffic than any other business district in the world. For the present purpose it cannot be enlarged.

2. Another condition practically unchangeable is the narrowness of the streets. In the business district referred to, Liberty is the only street more than 60 feet wide; and it is only 80 feet. Second, Third and Fourth Avenues are only 40 feet wide. In these narrow streets the operation of so many surface cars would be difficult even if it were not hindered by other traffic. In fact it is hindered by a very heavy

traffic of all sorts. Business is actually done in Pittsburgh under conditions which in most cities would be thought impossible. In such streets elevated roads are difficult and costly; underground roads are almost as difficult, perhaps as costly; and added surface roads are impossible.

3. A third condition to be considered is the grimy atmosphere of Pittsburgh. Elevated roads would add to the gloom of first and second floors.

4. A fourth condition which must be reckoned with in providing transit routes to the suburbs, is the hilly surface of the city. And as far as surface (or elevated) travel is concerned, the entire East End must be reached by only a half dozen avenues between Grant Street and Junction Hollow, a distance of two and one-half miles.

5. Another condition is the rapid growth of the population and of traffic. The traffic of existing street railways is understood to be increasing about 20 per cent. every year.

The Problem.

In order to solve the problem, the City of Pittsburgh must determine what new means of travel can be found, which will answer these needs and will fit these conditions. The problem is two-fold as it concerns (1) the relief of the congestion at the center, and (2) quick transit from center to suburbs. How can both objects be attained?

The Alternative.

Plainly, the needed relief must be found by building railways either overhead or underground. Both ways have been tried in other cities; and the result of their use must be a guide to Pittsburgh. Pittsburgh ought to profit by both the successes and failures of others.

For Pittsburgh there is but one side to this question, and that is, elevated roads should not be seriously considered. With much deference to those who have held the contrary opinion, it is believed that too much time has already been lost in unnecessary discussion.

The community is almost unanimous in objecting to elevated roads. But in order to present a view of the problem from every standpoint, the following suggestions are pertieent.

Reasons Against Elevated Roads.

(1) They would be ugly.

(2) They would be noisy.

(3) They would darken first floor rooms. And in dark weather Pittsburgh is too much afflicted already.

4 The columns and stairways would crowd the streets more, and in the narrow streets of Pittsburgh they would be a grievance. Space for them cannot be spared on the sidewalks, and there is even less room to spare between curb and car-track.

(5) An elevated railroad in any street would damage property enormously. In the business district the damage would be inestimable.

(6) An elevated railway must be reached by climbing stairways, and to that extent is inconvenient.

(7) Weather interferes more or less with the operation of an elevated road.

(8) Like all such things elevated structures wear out in time and must be renewed.

(9) The topography of Pittsburgh and vicinity makes the question of grades prohibitive.

(10) In the development of facilities for travel, elevated roads have had to be succeeded by something better.

The foregoing objections apply to elevated roads generally. In Pittsburgh there are the following additional objections.

(11) As they must usually follow the streets, and few of our thoroughfares are straight, elevated roads cannot be direct.

(12) Elevated roads could not be run through the business parts of the City; this, because of the enormous injury to business property and the amount of damages to be paid

therefor. And therefore they could not deliver and receive passengers close to the centers of traffic.

The fifth objection above stated deserves some comment. It is not enough to consider the cost of paying for damage to property. Payment would not compensate for the wrong done. To put an elevated railway into any street would work an injury to property owners which (merely as a matter of right and fairness) ought not to be put upon them if it can be avoided. When there is a better way there is no excuse or justification for it.

Reasons in Favor of Underground Railways.

(1) They would not be ugly.

(2) They would not be noisy.

(3) They would not shut out anybody's light or air.

(4) They would not take up any room in the streets, and its construction would not add even a pole to the surface of the streets.

(5) They would not damage property.

(6) They would be easy to reach.

(7) Weather would not interfere with operation.

(8) They would never have to be rebuilt.

(9) They would not have to be given up in the end for something better.

(10) As already suggested subways can follow more direct lines; and under such high ground as the hill district, they can be perfectly straight without any reference to the streets above. This shortens their length, lessens original cost, reduces cost of maintenance and equipment, reduces running time, and establishes a uniform and easy grade.

(11) Subways can be built through the heart of the business district, and can thus land passengers where they want to go. Subways can be located where they are most needed.

(12) There would be no electrolysis of city pipes.

The author recommends the underground plan without qualification.

The Terminal Loop.

Should the down town terminal of a subway be a terminal loop or a terminal station?

A terminal station would not be practicable or satisfactory, for several reasons. Taking the case of an East End Tunnel (for example), there are the following reasons why a terminal station would not do.

(a) On the smallest plan the area needed for a terminal station for the East End traffic would be about 44,000 square feet. The ground necessary for such a station on Smithfield Street, at any central location, would cost from $4,500,000 to $8,000,000. This is more than any road could afford.

(b) Such a terminal station would not deliver passengers where they want to go. It would be too far from their destinations.

(c) Such a terminal station would make the crowding of the surface worse in its neighborhood. If the East End traffic had to be turned out from such a station in the morning and taken on there in the evening, the crowding would be as bad as at Brooklyn Bridge in New York, and would eventually have to be rebuilt at great cost. The City of New York has just decided to spend $3,250,000 on the Brooklyn Bridge terminals and has already spent millions. Inbound passengers ought to be landed at as many places as possible. They ought to be landed as near their destinations as possible. They ought not to be crowded. And all this ought to be done with as little railway as possible.

(d) A terminal station would not be convenient for transfer to the lines running to Allegheny, the West End and the South Side.

(e) In New York, terminal stations have been tried, and have failed; and they are being abandoned in favor of the loop plan. There the most serious problem in transportation is now, how to get rid of such stations and to get loop terminals.

So, instead of a station, the terminal in Pittsburgh ought

to be a loop. What would be the size and location of such a loop?

In order to serve the people best the terminal loop should deliver passengers as nearly where they want to go as possible. It should run close to every part of the territory to be served; and at the same time, for the sake of economy and convenience, it ought not to be longer than is necessary for that purpose. It should be the resultant of resultants connecting the centers of gravity of the different business centers.

If such a loop should be made larger it would be too far from the places of business inside it. If it should be made smaller it would be too far from Duquesne Way and Water Street; and it would be too short to be operated with several stations.

This involves another reason against an elevated road. To avoid the greater damage to central properties, an elevated railway would have to be located in a wide circuit around the business district. This would increase the length, the cost, and the expense of maintenance and operation; and would increase the running time. And it would be much less convenient.

It would involve a maximum of cost and a minimum of convenience.

The Second Part of the Problem—Rapid Transit From Center to Suburbs.

For the lines in and out of town the rule for the best location would be the school boy's rule that "a straight line is the shortest distance between two points." Other things being equal the plan which should most nearly follow this rule would be the best.

From the central loop the out-bound tunnels may radiate like the spokes of a wheel.

Tunnels running to Allegheny, West End and South Side, can pass under the rivers; and the central loop can be made a common terminal and transfer place for all.

Construction.

The adopted form of construction has narrowed itself down to that of concrete arch, semi-arch and a circular cast ring. The first form adopted for the Boston Subways was that of a rectangle composed of steel columns, supporting a roof of eye beams, filled in on the top and sides with concrete, which has given way in recent and present construction to reinforced concrete arches which has been carried out even on special construction, such as stations, where possible.

The same holds true in New York except that under the Harlem from pier No. 4 in New York City to Henry Street, Brooklyn, a cast iron tube lined inside with concrete has been adopted. This type of construction has been successfully used in London for years past.

Anyone who used the underground railways in the City of London in the early eighties cannot have forgotten the punishment received from breathing the sulphur-laden air from the steam engine motive power. A trip, by day, through the Gallitzin or Sand Patch Tunnels will fully satisfy anybody's curiosity on this subject.

It was not until the introduction of electricity as a motive power and the adoption of the subway construction, that travel through a tunnel was made comfortable and it is an open question if time may not make it popular. If the capitalist and the engineer work in harmony, the subway can and will be made attractive for time saving and comfort alike. The antipathy to the "tunnel" will pass into history. Various kinds of waterproofing have been adopted in all recent subways and none have proven entirely successful; and there is no insurance for the condition of the waterproofing materials 25 or 50 years hence.

The question of ventilation has been perhaps the most vexing one the traveling public and the engineers have had to deal with. Boston has all but solved the problem. New York has collected volumes of data and seems to be trifing with the problem, though clearly understood. Let us turn our atten-

tion for a few moments to the problem of ventilation in the hundreds of coal mines in this vicinity. What are these conditions? A coal mine is like a city underground. Streets and dwellings on the surface; entries and rooms in the mines. Sunlight and air on the surface; darkness and deadly explosive gases in the mines. What is the law of the Commonwealth of Pennsylvania on the subject of ventilation of coal mines? In short, that they shall be made as healthy and as safe for the miner as the free air is for the toiler on the surface—is this a dead law? By no means; it has become just as essential to an economically operated mine as any other portion of the equipment. The question is properly asked, how about the ventilation, has it been solved yet, and if so, how? Yes, it has and by the simple method of installing a fan varying in size according to the mine. Boston has done this and New York will come to it when the public wakens up. Fans should be placed between stations of a capacity sufficient to completely exhaust or empty the subway in fifteen minutes; or in other words completely refill the tunnel with fresh air every fifteen minutes. With a system of fans of such capacity the supply of pure air at all times, cool air in summer, pleasantly warm air in winter, can be regulated to a nicety. In a City like Pittsburgh, most of the time dark and gloomy, with the air we breathe surcharged with soot and sulphur, it is a debatable question if fresh, washed air should not be pumped into the stations equal in volume to that expelled. The experts in New York practically all agree that the air in the subway is not unhealthy, but no one is especially proud of the results up to date in attempting to overcome the conditions without the introduction of a complete equipment of mechanical methods. It will call for the investment of considerable money to provide adequate ventilation, but will the inhaling and exhaling of air into and through a subway and tunnel be a complete relief? It will supply clean, wholesome air but how about the unsanitary condition of the subway itself; how about the tracks, the sides and ceiling? The tracks in the subway of New York are destined to give the engineers as much trouble as the

Brooklyn Bridge Terminals have the City of New York. The tracks of the subways now in operation in New York are the same as those of good surface roads, composed of steel tee rails spiked to wooden ties, supported on stone ballast. This sort of a track and roadbed is flexible in every sense of the word, easily aligned, repaired or replacd in case of wrecks. In the subway the making of schedules reckons with seconds and minutes, with the steam railroads it is with minutes and hours. Then too on the surface the maintenance department has the advantage of easy signaling, the convenience of cross-overs and turnouts and often change of routes, whereas in the subway there isn't even sufficient elbow-room, and the proper maintenace is vexing to say the least. Wooden ties soon begin to dry rot and give off offensive odors, the rock ballast catches and holds all kinds of filth and must in time breed disease. When the steam railroad manager wants a first class roadbed, how does he go about it? He sends in a requisition for heavy rails, the best and largest ties on the market and rock ballast. If this order be analyzed it will be found that, though the manager does not know it, he is nevertheless coming back to the girder rail, heavy enough to support the rail base load without serious deflection, or what is the same thing a continuous rail on a solid base. This sort of track has long since been discarded.

The subway engineer must take up this question again and adopt a track without tie and ballast, substituting a broad based rail, resting on approved packing or cushion of some kind held in position by heavy die-forged combined brace and clamps bolted to the rail web with slotted bases for allowing adjustment sideways, which in turn are held down by bolts not less than 1½ inches in diameter anchored into the concrete floor during construction. This will require a perfectly level base for the rail to rest on but once done is done for all time, and with such a track the cars will simply glide along. Then too the sides and top of the subway should be finished with white enamel brick on the inside and the floor cemented smooth. With such construction a specially equipped car

could sweep out a subway running at full speed, at which time the fans should be running at full speed removing all dust in the air.

All cars should be built of steel and non-combustible upholstering and have side and end doors so arranged that passengers leaving the car would alight on one side and those getting on the same car enter from the other side.

A subway system in the City of Pittsburgh has much in common with other cities, but much that is peculiar. The congested business centers and narrow streets require only a small double track loop to reach the business centers. On this loop the trains should all run in the same direction on both tracks, instead of running in opposite directions. The lower portions of the City are flooded annually, and this necessitates close attention to the arrangement of stations and absolute waterproofing.

The cost of a two-track Sub-surface subway such as is now in operation in New York, is about $275 per lineal foot. For an ideal one it would be about one-third more, say $365, but it is an open question if the extra cost is not after all money well invested, in view of the cost of maintenance of track and rolling stock.

There should be not less than three and possibly four stations located in the down town loop. It would be very convenient to have the tiling tinted of a different shade in each station. Those resident would know at a glance the name of the station and the stranger easily directed where to get off.

Motive Power.

No one in these days would think of adopting any other motive power in subways than that of electricity. The London Underground systems were slow in deciding to adopt the electric motor but have now had splendid opportunities to enjoy the comforts of electric driven cars.

The principal advantages are economy, convenience of application, entire absence of gases and fumes from fuel combustion, escaping steam, increased speed over steam power,

greater earning capacity per car mile and comfort of passengers, and there are many others.

As a matter of fact there is hardly a comparison to be made between steam and electricity as a motive power in which the latter does not show to better advantage. As to the question of three-phase and single-phase, alternating-current or direct-current motor, some better authority must do the deciding.

All things considered the third rail system of receiving the electric current is preferable to the trolley wire overhead.

With electricity as motive power the signals and safety appliances can be so arranged that the current will be automatically cut off, set the brakes and stop the train in case the motorman runs past a stop signal or misunderstands same.

Conclusion.

The New York Subways, in the local and express service are rapid transit, inasmuch as train service operated on schedule time is provided.

The Boston Subway is not a rapid transit line insofar as the trolley cars are concerned. No subway is a rapid transit line that is operated only by surface trolley cars entering it from the streets. The trolley car on the street is subject in all our large cities to constant delays; the size is dependent upon the narrowness of the streets; the speed, on the street congestion, which makes all surface car service irregular.

This must be constantly kept in mind and carefully guarded against, or there might be such a thing as a Pittsburgh Subway which would relieve the down town congestion without affording rapid transit, though both for the same expenditure of money could have been obtained.

Mr. Morse, having finished reading his paper on Pittsburgh Subways, continued extemporaneously as follows on subways generally:

We are naturally prone to think of Boston and New York as building the only and the first subways. For fear that there may be some of the audience who are not thoroughly familiar with the history of subway construction, I would like to say that away back in the sixties London had underground railways, which are now subways, and they were building extensively in the early eighties. London and the immediate vicinity has some 600 miles of local trunk and underground railroads. They are handling nearly 5,000 trains a day, and there are over 600 stations. Twenty-two of these are terminal, and the subways in the City proper are used to distribute from these twenty-two terminals.

Subways in London since 1887 are different from what we know as the New York Subways. The act of Parliament compels them to build below the surface so that they are not the cut and cover style of construction, the average depth below the surface being 50 feet. Then too it necessitates all the present subways in London to be tubes such as now adopted in New York in parts of the construction. Glasgow has five lines; short they are it is true, but they are as long as part of the Boston Subway under Washington Street. Berlin away back in the seventies, and recently in 1902 has modern subways and Buda Pesth has a model in every respect. So that we are not the only people who are contemplating the subject of subways. Boston has had subways in operation for a number of years and Philadelphia is building one. Chicago has several of a different type; freight systems. As a matter of fact away back in 1825 the first subway in operation in London was started, and it was built with a shield (just as they are using in New York to-day) without compressed air. This construction away back in 1825, finished in about 1845, was about 16 feet under the Thames and consequently it was

in the impervious yellow and blue clay which underlies the City of London and did not let the water through. The style of tunnel that London by act of Parliament is building exclusively and the line that is just finished and turned over to traffic six weeks ago, the Great Northern, Piccadilly and Brompton Railway, one of the most modern types of that style

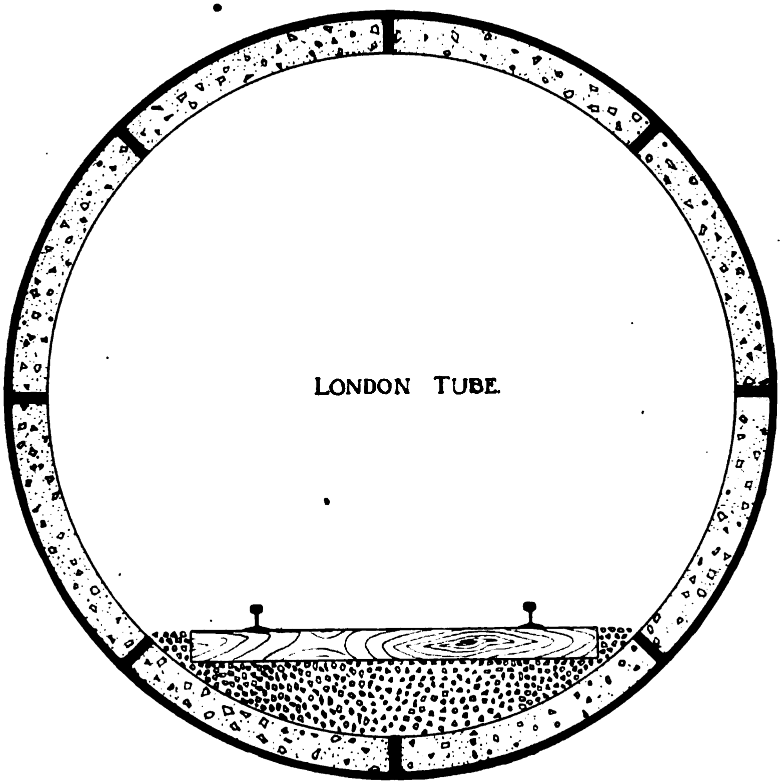


FIG. 1.

of construction is shown in Fig. 1. There are two tubes about 25 or 26 feet apart and there is only one track in each. The tube is about 11′ 8″ in diameter. The first was 11′ 2″ and now it is 11′ 8″, and 12′ on the curves. That (Fig. 1) is also almost identical with the style that New York is building under the Harlem from Pier No. 4 across to Brooklyn.

In case of wreck or power giving out, or the light going out, and a good many other conditions that all seem to come together at once; it has been very embarrassing in New York, and especially in Paris where they have had one or two very bad accidents by people getting out and walking on the third rail, and on the wrong track, and getting all mixed up. The Pennsylvania Tunnel under the Hudson River has an allowance for a sidewalk four feet wide on each side. This adds very greatly to the cost of construction, but I am satisfied it will pay in the long run. The spaces under the sidewalks are also used for conveying pipes, etc.

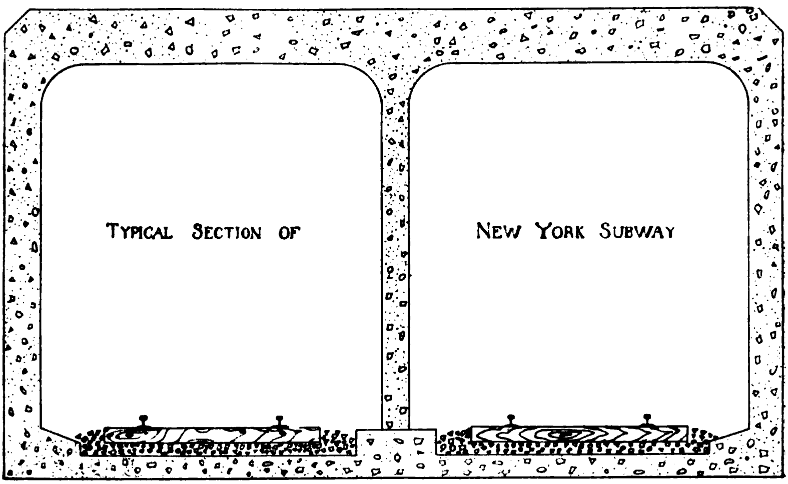


FIG. 2.

Regarding the question I have already mentioned: The problem is to get the smallest loop that will meet all the requirements of all the trade in the City of Pittsburgh. A proposed loop going down Oliver from Webster Avenue, and Liberty to Ferry, up Third and back Grant to the place of beginning, is represented on the map at the end of this article. The object aimed at is simply to locate a loop almost an equal distance for the traveling public from the outside and center. The location of stations is one that in

the City of Pittsburgh is a very vexing problem. There are no parks with the exception of one on Second Avenue. None are in the down town section or near enough, or anywhere near large enough for a terminal station or an entrance to one. To meet the needs of the traveling public there should be four stations to the proposed loop.

The question of a terminal station has another meaning. The congested portion of this City has no place for a terminal station; the terminal stations to be effective must relieve the congested portions of the city. Imagine a terminal station anywhere on Smithfield Street from Sixth Avenue to the Post Office, and turning out the whole of East Liberty there! The surface cars could hardly pass through the streets with pleasure and safety to men, with no thought given to the ladies; so that when the question of location, of purchase, and of length of a station is discussed for subways in the City of Pittsburgh, it will require careful planning.

I have made the remark that the trains should all run in one direction in the loop. I have an object in that, in fact, two or three of them. In the first place signals can be so arranged that the passengers know just where to stand for a car that is approaching. By having two tracks with trains running the same direction, they are running with the travel and there is no danger of a head-on collision. The trains can be switched over to either side of the platforms. In studying the travel at Park Street Boston I was impressed with the advantage of an island or center platform. The station should not be less than 250 feet, better 400 feet long. It will then make no difference whether the train arrives on No. 1 or No. 2 track. Those getting off would alight on the side platforms and it would make no difference to them which one. By such an arrangement more than twice the number of people could be handled without confusion.

The real vexing question in New York is that of ventilation and when I say ventilation I mean especially heat, because it has been shown by Dr. Sopher that the carbon dioxide in the tunnel varies slightly from the outside air, that the air

is as pure as the average office building. That there is an odor, and that that odor is due in part to oil in the atmosphere, but especially to floating particles of iron in the air, due to the grinding up of the brakes, there can be no doubt. The temperature within varies with the heat outside, from 6° to 25°, and during the summer time it will average from 6° to 10° higher than the outside temperature. In London the train operates as a piston, filling the whole tube, yet all the new roads have been equipped with a complete system of ventilation by fans. The action of the piston is not satisfactory, it forces the air out of the tube on approaching stations and sucks back a portion of the same air on leaving. Mr. Parson says in both reports, on the New York Subways, especially in the one for 1905 which is just out, that the ventilating in the Manhatan-Bronx Subway is not satisfactory and it must be overcome. Dr. Sopher confirms him. Mr. Parsons says the ventilation must be mechanical. What does he mean? I have never asked him. When the fan stopped two years ago in the Boston Subway the papers came out with a great spread on the subject of ventilation. Mr. Carson, Chief Engineer, said that it was due to a breakdown. The public pulse detected it mighty quick and when the breakdown came they noticed the difference immediately. When the fans are in operation there is no question asked about ventilation.

In New York they say the air is pure. I can't doubt it; reports are better facts than I can give you; but I do know if I want a good splitting headache let me ride two hours in those subways. I do know that the odor in the Boston Subways is but slight; the air was almost too cool. Why? Because the fans were running.

Mr. Parsons says in his 1905 report that the amount of expended energy at the stations and in the transmission of the cars, stopping and starting, means an expenditure of lost energy amounting to 83%, which is the real source of heat given off. and absorbed by the tracks platforms sides and top of the subway. In London Subways they approach most of their stations on an up grade of one in six, that is about 1.7%,

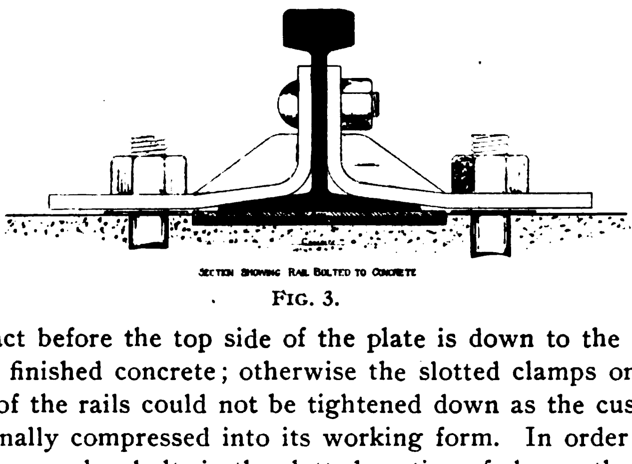
and they leave the stations with a down grade of one on three, 3.½%. The object is to overcome the tremendous loss of energy and the generation of heat in stopping trains by mechanical means. We have not adopted this method but it is an open question if we should not.

I know of no positive method of getting fresh ai by coaxing it. They are trying it in New York, they are doing a great lot of coaxing; it does not come. But I do know of mechanical methods that are a success. The fan system is entirely so. It is not reasonable to expect that the Great Northern, Piccadilly and Brompton Railway would install fans unless assured of success. And right there in London others were using them successfully. No one can deny the fact that Boston is getting really good, fresh air, with only a whiff of odor. The odor comes, to my mind, not only from the oil, etc., as previously stated, but especially from the track; and that is why I said it is a debatable question whether fresh aid should not be pumped in at the stations. Mr. Parsons says in his report that most of the heat is generated from the motors; that they heat up to 150° and that radiated heat must go directly into the track, and on the sides into the platform; and as the platform at the track is made like a channel the heat is held in during the time the train is stopped. For that reason I am of the opinion that any well designed subway should pump the air in under the platforms at the stations. Whether it should be exactly the amount that is pumped out is another matter.

The question of ventilation is also dependent upon a factor that enters into that of the construction of the track. That is a subject I have probably given as much care and thought to as any other. In Boston and New York my attention was called to the fact that I could not tell what the tracks were ballasted with. They were filled with dirt in many places nearly to the top of the rail. Where trains are scheduled as close as they are in New York how will it be possible to keep the tracks clean? It is a problem that the Maintenance of

Way Department in New York will spend a good deal of gray matter over and then not solve it with satisfaction.

After making and discarding numerous designs, I have finally adopted the method above described, and shown in Fig. 3. In finishing a roadbed for this style of construction, it is first necessary that the troughs be finished to mathematical precision, which I will admit is an expensive thing in first cost, but once done is done for the lifetime of the structure. The trough should then be filled under the rail with some kind of a resilient substance, like fireproof asbestos for instance, made into belt form of any convenient length, which should in turn be covered with a metallic plate of a thickness sufficient to allow of its extension above the finished concrete on each side of the trough sufficiently to permit the cushion to become



SECTION SHOWING RAIL BOLTED TO CONCRETE

FIG. 3.

compact before the top side of the plate is down to the level of the finished concrete; otherwise the slotted clamps on the sides of the rails could not be tightened down as the cushion was finally compressed into its working form. In order that the large anchor bolts in the slotted portion of clamps that are bolted to the web of the rail shall have more than enough adjustment to meet these conditions, it is believed wise to at first insert a washer under the nut on the bolt shown in the figure, which can be removed at will. Slots in the plate should be made for an allowance of ¾″ side adjustment to meet the wear of the rail. The anchor bolts should be at least 2″ in diameter, firmly anchored into the concrete base during construction. I am of the opinion that the rails should be at least 8″ high and

8″ wide at the base. The depth will permit of a heavy fish plate at the joints and the extra width of base will provide against side thrust and be a safeguard against accidents caused by the spreading of the rails. I believe that a track built on these lines is fully as safe as the present method of construction, it certainly is cheaper in first cost and is many times cheaper in maintenance, adjustment and replacing, than a rail and tie on ballast, and when it comes to a question of sanitary condition of the roadbed of a subway, there is no comparison. With such a track there wuld be no excuse for the accumulation of filth that is to be seen at present at every station in the Manhattan and Bronx Subway, New York. All curves and cross overs, frogs, and switch points should be made of manganese steel.

Fig. 4 represents a plan worked up by my assistants, Barr Brothers, for cut and cover construction. This method permits each side of the subway to be completed with the maximum amount of speed and the minimum amount of annoyance to the public. It contemplates the opening of one side at a time, the finishing of part of the bottom foundation and side to a point just below the street which will be decked with plank until the opposite side is completed in the same manner, when the two sides are covered over with either metal or reinforced concrete construction and the street repaved. The removal of the balance of the excavation will be by steam digger and trains of dump cars operated through the finished portion of the subway and not on the surface of the street. After the excavation is completed the unfinished portion of the bottom of the structure will be concreted. The above excavations should pass out from the subway say at the corner of Ferry Street and Third Avenue to Water Street by a small secondary tunnel and be dumped into boats for down river distribution, or better still used as a fill in Lower Allegheny.

I would like to be permitted to make a prophecy based on the increase of travel in the last ten years—here is a little extract I will take the time to read:

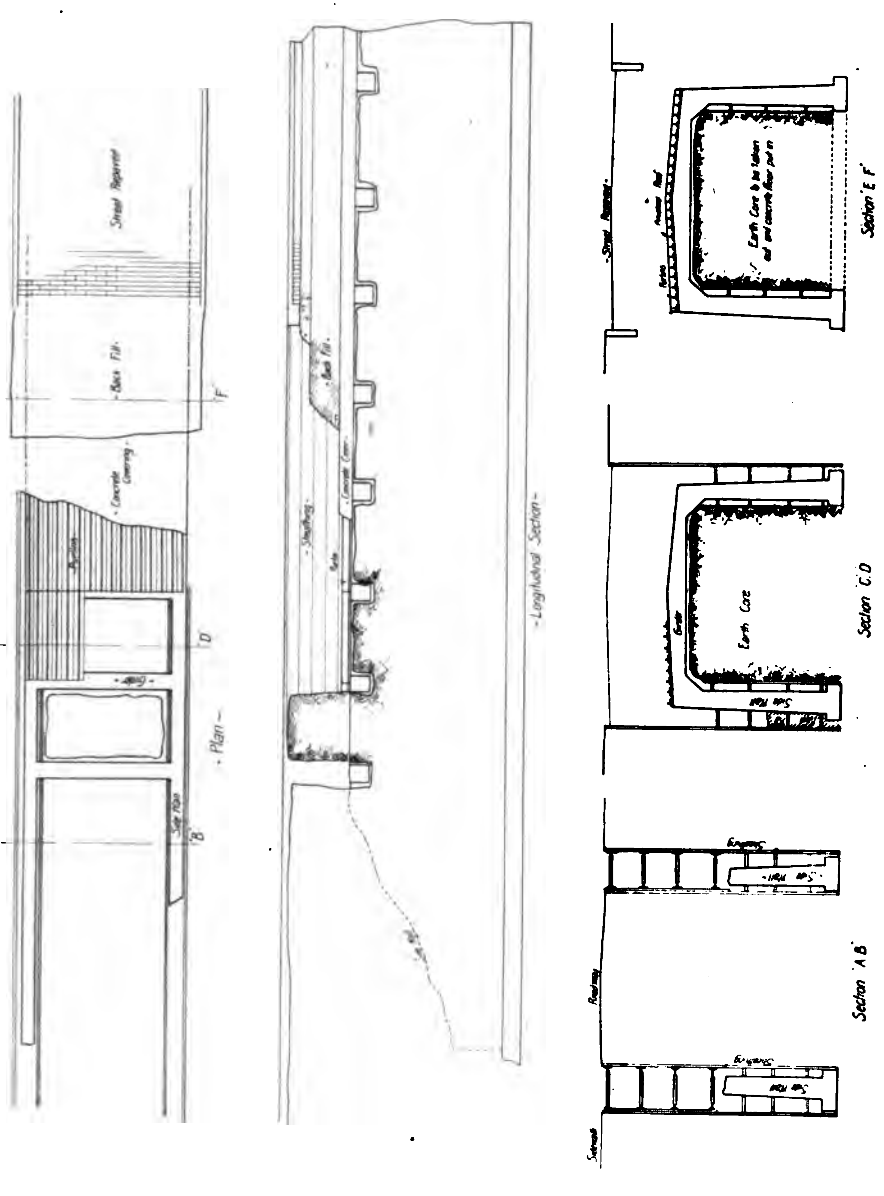

Plan
Longitudinal Section
Section A B
Section C D
Section E F
Earth Core
Back Fill
Street Pavement
Side Wall
Girder
Roadway

Figure 4.

"Scarcely fifty years ago the rivermen had everything to themselves. There were no bridge piers and nothing else to mar their pleasure except the bars. Iu the early spring of 1852 the first freight shipments by rail out of Pittsburgh began, and in 1895 they had increased from nothing to the enormous figures of 35,000 000 tons during a period of forty-five years."*

If you will multiply the tonnage of 1897 by three and add 30% to it you will have the estimated tonnage for the fiscal year. What does this mean? What is London doing? What is New York doing? Two of the greatest cities in the world. London discharges to-day in the down town district, in the business district, 500,000 passengers before 10 o'clock daily. London is hauling 600,000,000 passengers a year by the three systems I mentioned, and is preparing for 6,000,000,000 in 1915. The City of New York has plans made to-day for 1,200,000,000 and is completing plans for 3,000,000,000. These are large figures but they are coming with absolute certainty and absolute precision. What will be the condition of Pittsburgh in ten years? There will be no question about the tonnage increase. We do not question the fiscal year's estimate. Here are three great rivers, the Monongahela, Allegheny and Ohio and a very narrow margin of bottom land there is left for business. In 1896 the first steel car came into this section. We were then able in 35 feet (coupled up) to haul 50 tons of load with 10% excess. I might almost say that if it were not for the steel car Carnegie would have gone to the Lakes in 1897, and then Pittsburgh would have had another history. I know that nearly every good available mill site between here and Rochester is gone and they are going down the Ohio as far as Smith's Ferry; and New Castle and Youngstown think they are equal to Pittsburgh in importance, and they will soon give us a chase. It means that the center of gravity of the tonnage is moving west. I question if it will go up the Monongahela River as it has done in the past, or anything like it, and I more seriously question if it will go up the Allegheny. I can't see it going any other way than where it comes from, towards the

* Proceedings Engineers' Society Western Pennsylvania, 1897, p. 219.

[illegible]

Great Lakes and the Northwest. But if the tonnage of Pittsburgh is going to grow in the next ten years anything like what it has in the past ten, what is going to be the result? Herein I believe might be the solution of the whole problem. I am satisfied whether the present Company I am with builds a subway or not, subways will be built in this city. I see no other solution. I have in my life seen but two statements (for officers of the road only) of a railroad's earnings. One of these statements showed the earnings of freight to be five; the earnings of passengers to be one. This was not the Pennsylvania, but it does lead to the remark that Mr. Robert Pitcairn made that passenger traffic to a railroad is simply dress parade. Therefore, the earning capacity of railroads, to my mind, is going to be the governing factor, and that is freight. And I question if you are going to put more than fifty or seventy-five tons in a 35 foot space. Consequently the railroads must relieve their systems and their track to the maximum. They must, in other words, give up as much of their passenger traffic as possible and must give the right of way to freights. To-day the freight train is sidetracked for the local or any other kind of passenger train, but after all it is the greatest earning factor. How else are the railroads going to meet this tremendous increase in tonnage? I believe the Pennsylvania will land all local passenger travel at East Liberty and subways will bring it into the City. I believe the Ft. Wayne will stop local traffic in Allegheny; the P. & L. E. and Panhandle will stop local travel down at McKees Rocks and subways will be built from Pittsburgh through Allegheny and under the Ohio River to McKees Rocks. There is no prettier residence section in Allegheny County than the Chartiers Valley, but would anybody from Alegheny think of going there? There are no facilities to get there. What is to prevent a subway from going over to Federal Street and down to McKees Rocks and from there rapid surface street cars radiating in all directions. I believe the railroads will in time solve the problem this way. Not to-day, for that is not the railroad way of doing things, but I do believe they will come to it. Not per-

haps through their own free will, but the 7% dividend will make them. And when the railroads are relieved from the local passenger traffic they have nothing but express, mail and through passenger traffic; the local will be entirely eliminated.

DISCUSSION.

The Chairman: Gentlemen: As you will notice we have several gentlemen who have promised to lead the discussion along different lines, and in view of the fact that there are a number here who will want to bring up other points, I will ask them to try and limit their discussion to five minutes or less. Mr. Storer, who was to discuss the question of Electrical Car Equipment, has been called from the city and Mr. Renshaw, of the Westinghouse Electric Company, has kindly consented to open the discussion of that topic.

Clarence Renshaw, Non-member: I was unfortunate enough to miss the first part of Mr. Morse's paper and do not know whether he said anything in regard to the equipment of the cars, but I venture to say from general experience that the operation of the cars is the part of the subways which gives the least concern of anything connected with it. It has probably been taken for granted that electricity will be the motive power. This almost goes without saying because there seems to be no other motive power that will do the work. There is one thing, however, which electricity cannot do, and that is impossibilities. So I trust that in the alignment of the Subway sharp curves will be avoided. At the time the New York subway was being planned I did a little work in connection with the figuring out of the schedules. It was at first proposed to make a schedule of 30 miles an hour for the express trains, but owing to the curves which were put in, this was impossible, and it had to be cut down to fifteen and possibly a little lower.

It does not seem to have been brought out whether it is proposed to operate the cars by an overhead trolley or a third rail. From the fact that certain of the trains will prob-

ably never leave the subway, it seems likely that all those trains will be operated by a third rail system. On the other hand, since it is also possible to use subways for surface cars, it will probably contain an overhead trolley as well. In regard to the equipment of the cars themselves this will probably not involve anything particularly new or startling. The equipment of electric cars has now been brought very near perfection. The cars will undoubtedly be operated by the multiple unit system in which a number of simple units can be coupled together and operated simultaneously from the head of the train. Undoubtedly also these cars will be so arranged that in case of accident of any sort the power will not only be cut off but the brakes will be set. These features, though not in common use in this vicinity, have been used in other places and therefore are not particularly novel. Even the surface cars have been equipped in a more or less similar way, so that it will be possible to couple a number of cars together in one train operated by a single motorman, and thus save time and increase track capacity over what would be possible if a large number of single cars were operated individually. And surface cars in this way can be run as a train through the subways and then separated at the mouth with little or no delay and scattered through all parts of the country.

The Chairman: Mr. Johnson will now discuss the question of road bed and track construction.

Thos. H. Johnson: Mr. Morse has so fully discussed the subject that there is little left to be said. In the matter of road bed from the very nature of the problem the floor of the subway must be concrete. But what is to be placed on that road bed may be the ordinary construction of cross ties and ballast, or longitudinal stringers bedded in concrete, or two or three other modifications that might be mentioned. But Mr. Morse has emphasized one thing which is an unusual requirement in ordinary track work, but of very great importance in constructions of this character; that is the facility for convenient cleaning. And the scheme he has outlined seems to be in that direction, although I would not follow it ex-

actly in detail. I would suggest a steel longitudinal stringer under the rail, bedded in concrete, with the rail attached to it with suitable bolts and clips. On the matter of noise, either such a felt as he has described, or some other substance now on the market, such as indurated fibre, less expensive than asbestos felt.

The Chairman: Unfortunately Mr. Cummings cannot be here. He has prepared a paper on the topic of reinforced concrete contruction which Mr. Livingstone will read.

Reinforced Concrete Construction.

After several years of experience reinforced concrete is now recognized as a structural material possessing certain points of superiority over structural steel or masonry. It has been used to great advantage in recent subway construction in Philadelphia, New York and other Eastern cities. It follows, therefore, that its application to the proposed subways of this city is not without precedent. Among the inherent advantages of this new structural material may be mentioned:

First—Its durability.

Second—Strength and resistance to vibrations.

Third—Its fire resisting qualities.

Fourth—Facility and speed of erection.

Fifth—Economy.

It is almost universally conceded that these items are among the meritorius features of this material. There are, however, other points of interest which may be profitable for us to briefly refer to this evening, especially in connection with the subway problem in this city.

While it has not been my privilege to examine the plans of the proposed subway in which reinforced concrete construction is shown, there are certain features of its application that out of necessity will require special treatment. Among these the problem of waterproofing the concrete is perhaps one of the most important. The necessity of a dry and watertight subway is apparent to every one, so that the means for secur-

ing this object must be very carefully studied. Hence, my remarks will be confined to the waterproofing of concrete.

In general there are two methods of accomplishing this object. On the one hand the concrete of itself must be made waterproof, on the other hand there must be a water resisting and watertight protection to its surface. Both methods have been used in my practice, the applications varying with the conditions surrounding the structure and the facilities for execution.

In order to secure the best results by the first mentioned method, the concrete ingredients must be carefully and accurately measured and proportioned and systematically deposited in rigid watertight moulds, under the direct supervision of experienced inspectors employed by the contractor specialist.

It is unfortunate that there are very few contractors who have the desire, knowledge and experience necessary to undertake such work. This is, of course, not due to constructive inability, but rather to the usual methods of procedure in contract work, wherein price and not quality of the work is the ruling element. Besides, the ease with which ordinary concrete is made discourages the use of a better material for which there is very little demand. Yet there is a simpler method than the making of this special quality of concrete. Watertightness can be secured by incorporating into the ordinary concrete a waterproofing compound of hydrated lime or other similar materials. There is of course some danger in using such compounds unless properly applied. Cracks may develop in the concrete and thus render the waterproofing medium inefficient.

While it is customary to expect to find cracks in concrete work, if it is properly designed and properly executed by careful, systematic and thorough inspection of all materials and workmanship entering into its manufacture or subsequent exposure, there is no plausible reason why concrete should crack. It is the absence or neglect of one or more of the requirements that will invariably account for cracks and failures in concrete work. But concrete without cracks is perhaps too near the

ideal. There are too many uncertain conditions in the execution in which the human element controls, to expect that the construction on a large scale could be carried out without the existence of one or more of these causes; besides to carry them out the cost would be unreasonable. You will therefore see that I am very much disposed to eliminate the above mentioned method of constructing the concrete work in its practical application to the Pittsburgh subway.

The alternative and second method is to apply a *protective waterproofing coating to the surface* of the concrete. This of course should be applied between the concrete and the water pressure. The best method of accomplishing this will depend very largely upon the detail design of the subway, so that no attempt can be made at this time to suggest details of construction. No doubt a practical and efficient system of perfect waterproofing can be designed and applied at small cost: There is no necessity of appealing to the so-called "patent" waterproofing processes. The most suitable water resisting and waterproof medium known to me is the *ordinary coal-tar.* This material has been preferred by the Pennsylvania Railroad in the construction of its tunnels under the North and East River, New York. It has been proved by a great many years' of experience that it does not deteriorate, harden or crack when under ground and not exposed to the atmosphere. In this respect it is very superior to asphalt, which disintegrates when in contact with water. It is easily obtained and applied to the surface of the rough concrete. Of course bituminous concrete can be prepared which will give practically the same results, but it is thought this would be found more expensive. On the other hand a plaster coating of cement in which a water resisting medium is incorporated can be as readily applied as the coal-tar protection, but there would be a danger of cracks appearing in such a mortar which would destroy the results desired.

It appears to me that the waterproofing of the reinforced concrete for the Pittsburgh subway can be secured by a protective coat of coal-tar applied to the surface of the concrete

so that there will be no mechanical abrasion or disposition to penetrate this protection. The details of accomplishing this may be left to the skill and judgment of those able engineers under whose guidance this enterprise will be successfully constructed.

The Chairman: One very important element in the operation of a subway system is that of the signal and safety appliances. Mr. Thullen of the Union Switch and Signal Company will give us some of the general principles of this subject.

L. H. Thullen, Non-member: The question of signaling is one of such great importance that it is rather difficult to deal with in in so limited a time. The objects of signaling are two-fold: The *protection* of traffic, and the *regulation* of traffic. In this country automatic signaling has been adopted very extensively, while in England and on the Continent manual control has been used to a great extent. This is due very largely to the fact that in this country labor is high. In fact the signaling situation in this country has reached such a state of perfection that it is nearly infallible. All parts are designed with a large factor of safety, and are thoroughly tested in every way imaginable. They are designed upon the principle that a break in any part will set the signal at danger position and never at clear position. This is one of the fundamental requirements of any signal system. Signal systems are mostly operated by electric control on a closed circuit, so that in case of an open circuit the signal will be set at danger. In fact there is no condition that I can think of where a signal would be likely to set at a clear position when it should be a danger signal.

On the Continent the signals are operated manually and it depends on the judgment of the person who is operating the signal and upon his reliability. As we are pretty thoroughly acquainted with this feature of the human race we know that men are not entirely infallible.

In connection with the signaling system of the subways it is necessary that the signal be extremely small. In New

York the available space is about eight inches along the side of the tube. The signal in this installation, which represents a typical installation, is eight inches wide and is a *light* system strictly. Electric lights are placed behind a colored lens and the different colors designate the clear or danger signal. These signals are controllable by a track relay, and the track relay by an alternating current relay; inasmuch as the propulsion current is direct current and it had to be of such a class of operation that direct current would not operate the signal. A transformer is placed so as to fit into a track circuit at one end and the relay is connected at the other end. Five volts is the maximum amount of alternating current used for track circuit. The relay is shunted by the train. At the passage of the train into the block the alternating current is given to the transformers by means of 25 volt mains extending throughout the subway. This system of signals has given very fair satisfaction. The report of the signal engineer shows that the total number of failures was exceedingly small.

According to the report for October, 1906, there were about 400 signals in these subways, and the number of trains that operated them made an actual number of 6,718,346 signal movements in 30 days. Against this is charged the different failures due to different causes. There were 14 failures of signals, and in all cases the signals were set at danger when they should have been clear, and in no case was a clear signal given when it should have been a danger signal. Therefore, there was no danger otherwise than the retarding or holding up of traffic. Broken wire caused two failures, that is the wire running to the relays or any part of the apparatus. Most of the broken wires are where the wires come underneath the binding posts, etc. Three failures were due to broken bond wires. A broken bond will set the signal at danger the same as a broken rail, as it breaks the track current that supplies current to the relay. One failure was due to the relay; what caused that is unknown. Sometimes the contacts get glazed over and the circuit is interrupted, and that makes a danger signal when it should be clear. One failure was due to the

blowing out of a fuse. Four failures were due to the insulating joints. One of the rails is divided off into 8-inch sections and it was necessary to put in an insulating joint to make the entrance and exit to a block; and the bridging of a joint will sometimes cause a failure. One failure was due to the track main and one to a piece of broken umbrella bridging an insulating joint. Another was dirt in one of the valves, making a total of 14 failures in a month, which would be one failure to every 479,881 movements. When you consider that all these were danger signals, when they should have been clear, it makes it, you might say, practically infallible. The signals are spaced from 800 to 1,200 feet apart, the spacing being derived from the braking distance of the train running at a theoretical speed of 40 miles an hour, and 100 per cent. being allowed. I think the theoretical braking distance is about 400 feet and to that 100 per cent is added, making 800 feet. Then on grades and curves the distance is lengthened or shortened.

The Chairman: Mr. Clifford will close this branch of the discussion with a discussion of the subject of Ventilation.

William Clifford: I have given some attention to the subject of ventilation of mines, and a subway is a simple form of mine. A recent paper read before the Mechanical Engineers on the Boston subway, shows a very easy way of ventilating subways by a fan placed midway between stations. The fan need not be large and I do not think there is any need for a brattice or partition. In the summer time the whole of the fans could be operated; in the winter say half of them, as the doors of the stations are mostly closed in the winter time. I have examined the New York subways and have the plans, and my conclusion is that the persons responsible for the design of that subway did not think anything about ventilating it, and they are trying now "how not to do it."

In the Rapid Transit Commission's office can be seen elaborate tabulation of observations, barometric and other similar data, extending over eight months; but those conducting these observations appear to have no idea of passing a

current of air through the subway just as we pass it through a coal mine.

Adopting an arrangement similar to Boston would improve things. This would mean a ventilator say half way between every station. A large volume of air would be necessary to deal with the dust. Therefore the installing of a single ventilating station of large capacity for say ten miles of tunnel would be a very much simpler way of remedying this. I would also deal effectively with the problem of refrigeration.

Some coal mine clients of mine asked me to go to New York and examine into the ventilation of the subway, and see what could be done. I went there and found the whole business in the hands of the Rapid Transit Commission. I have a scheme cut and dried when they are ready. I was told that when the Commission had done all they could, or admit that they could do nothing, they would call on somebody who would do the job in a practical way.

The Chairman: The question is now open for general discussion.

W. A. Bole: I would suggest that gas mains should be kept out of the tunnel. It would be a very bad thing in case of accident, such as the breaking of a main, passengers might be asphyxiated.

Mr. Clifford: Mr. Morse's paper is likely to spoil a pet scheme of mine that I have had in mind for years, for dealing with the sewage of Pittsburg. That is the driving of a tunnel under the river to a shore site distant from the city, and there pumping the sewage to some point where it could be dealt with by intermittent downward filtration, or process, on a sewage farm. The lower town subway might disturb all that.

Mr. Morse: There was another question raised as to sewage. Take Fifth Avenue, for example. It has one sewer down to Wood Street and down that way (illustrating). The other goes over to Sixth Street and empties into an 18-foot sewer.

Everything in that space there (indicating) must be entirely rebuilt and ought to be rebuilt today. Any subway undertaking to build there must stand that or the big end of that rebuilding.

Mr. Clifford: My idea was to convey all the sewage to a pump where it could be pumped away from the system to some works for, or method of, treating sewage.

Mr. Morse: Let the Commonwealth of Pennsylvania pass a law compelling everybody up the river to do the same thing, otherwise there would be no sense in the City of Pittsburgh going to that expense.

Mr. Clifford: The prospect seems to be that Pittsburgh and up-river towns will become so large that the river will be simply a huge sewer, unless something is done.

F. C. Schatz: I would like to ask how they propose to get rid of the sewage that is created within that rectangle. Will it flow by gravity or will it have to be pumped?

Mr. Morse: The present plan is to drain all the sewers inside the loop to a lateral sewer down Wood street passing under the subway at Wood and Third Avenue.

Mr. Schatz: Would this affect present levels as they exist now in this section bounded by Liberty, Fifth and Ferry? For instance, the Empire Building has a sewage system which drains into the Allegheny River. Under the proposed system will that sewage system be influenced in any way?

Mr. Morse: Yes, the whole system will have to be rebuilt.

Willis Whited: Mr. Morse spoke of one thing that looks to me as though he had a little the wrong idea. The heat there all comes from the transformation of mechanical energy, and it radiates mostly from the coils, etc., and particularly the motors, and also from exudations from the people in there.

Mr. Morse: Two per cent of the heat comes from human beings and the balance from operation of trains.

The Chairman: In connection with the heating of elec-

tric motors it may be interesting to know that the energy that is at present lost by brakes is on some of the systems being returned to the lines. The cars in braking are using their motors as generators and returning the energy to the line and not simply expending this energy in useless work in braking.

Mr. Clifford: Referring to temperature in coal mines where, in shafts newly sunk, the skin temperature of the strata was 100° Fahr. in five years, that has been frequently reduced to 60° by ventilation alone.

S. B. Ely: I would like to ask what is the depth of the subway when you get pretty well out of the city, say along at Oakland.

Mr. Morse: From 150 to 300 feet below the surface.

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S. M. KINTNER, President,

In the Chair.

The Automobile.

BY FREDERICK L. GARLINGHOUSE,*

Member.

In writing the history of civilization it has been found convenient to separate the various periods, according to the characteristics prevailing, into ages, such as the Stone Age, Bronze Age, Iron Age, etc. Now that steel has about supplanted iron, it has been proposed to call the present period the Steel Age. This might be appropriate from one point of view; but unfortunately—or fortunately perhaps—there are other claimants. Steam looms up as a big factor, and the Age of Steam has been suggested. Since electricity has come forward with such prodigious strides, enthusiasts in that line of work say the Electrical Age would better serve the present condition of things. But we have motors of all kinds for doing our drudgery, such as steam motors, compressed air motors, hot air motors, water motors, electric motors. Why not call it the Motor Age? That would seem quite appropriate, if we

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did not stop to reflect a moment, when we realize that back of the motor is the designer, the genius who creates it; in other words, the Engineer, so we are forced to call the present the Engineering Age. The Engineer is the Wizard who has made old Mother Earth move so fast in the past one hundred years that we scarcely know where we are, or whither we are going. Archimedes discovered the principle of the lever, and only wanted the fulcrum to move the world. At the pace we are going, I think it safe to say that modern scientific engineering has found the fulcrum.

Will the pace be maintained, or augmented? Why should it not be maintained, and why is it not reasonable to anticipate an increase? It has taken a century, probably much more, to get men thinking along right lines. Now that we have acquired the habit, why should we not continue it? If a cylinder is started from a state of rest at the top of an incline, it at first moves slowly, but gradually, acquiring momentum, the speed is continually accelerated, so that if the incline is infinitely long, an infinite speed would finally result, provided other forces were not developed to check it. But other counter forces are generally excited, which increase with the augmented speed of the cylinder, so that finally the two forces balance and the cylinder moves at a uniform rate. The scientific spirit may be likened to the cylinder, with the inclined plane just departing from a dead level at first, and for a long distance, so that the movement would be so slow as scarcely to be discernible. However, for a thousand years before the Eighteenth Century it had been gathering force, so that an impartial spirit of investigation had been pretty well inaugurated by that time, with the result that for the past one hundred years the amount of knowledge accumulated and applied for man's benefit has exceeded *all* that was known before *in the whole history of civilization.*

Those of you who attended the World's Fair at St. Louis must have been astonished and delighted at the very complete —I don't know as I would be much wrong in saying the absolutely complete—exhibition of steam vehicles. There you

saw the first crude, clumsy and almost ridiculous wagon to run on a highway, up to the modern Leviathan running on our most progressive railroads. In all stages of development, you saw the germ of locomotion worked out: over one hundred years of study before you.

Probably the locomotive has been, and continues to be, the motor upon which the most brain power is expended. The problem, in the main, is to make it more and more powerful and economical. Heavier trains must be handled and more of them to meet the growing demands of the country. At the present time the railroads are taxed to their utmost to take care of the business offered, and this business must increase with the increase of population. The supreme importance of improving the locomotive is therefore justified, for our very existence almost depends upon it. Perfect as it is, as a piece of mechanism, the available units of heat are small compared with the total units in the fuel. It is a spendthrift in spite of all the skill and cunning which has been lavished upon it. It was long the dream of inventors to combine the boiler and engine in one machine. That is, burn the fuel where it is used to produce work, or in the cylinder. Gas engines were developed from this idea, and we have many efficient ones today.

The generation of gas from solid fuel was parent to the thought of getting the same result from liquid fuel. In 1885 Daimler took out a patent for his high-speed gas or mineral spirit engine, which he applied to the propulsion of carriages. I believe he is considered as the "father of the automobile." Other engineers, profiting by this invention, began experimenting, especially in France, as Panhard, De Dion and Mors, names now familiar in the manufacture of motor cars.

About 1890 the development commenced in this country, and has come forward with amazing rapidity since 1900. It is scarcely more than a decade since the invention of the gasoline motor. We, therefore, see that nearly as much has been accomplished in ten years, in the perfection of the Automobile, as has taken a century in the creation of the locomotive. Ap-

parently showing that the engineer of to-day is ten times better equipped to handle any mechanical problem than his brother of a hundred years ago.

Now let us see what are some of the requirements of a successful motor car. The following are the most important: The motor must be powerful enough to propel the carriage over rough and hilly roads, at a fair speed, say, six to ten miles an hour in this vicinity. The power should be so applied as to get a maximum result. This will naturally require a proper distribution of weight on the wheels. Ease of control, by which we mean not only the application of the power, but the guidance of the vehicle; that is, the steering mechanism must be easily operated and effective. Comfort in riding, where rough roads are encountered. Ability to stop quickly, either on levels or inclines.

Most gasoline motors are of the four-cycle type. That is, there are four distinct operations, being continually repeated in the running of it.

First: Inspiration—Our mechanical horse must have the breath of life, which is, in this case, gasoline vapor, and air.

Second: Compression—The vapor and air being compressed to about 70 pounds per square inch on the return of the piston.

Third: Explosion—The charge being now ignited on the second downward stroke of the piston.

Fourth: Exhalation or Expulsion—The burnt gases being expelled on the second upward stroke of the piston. We are assuming that the cylinder is placed in a vertical position in speaking of downward and upward strokes of the piston.

Further, it must be remembered that the power impulses are only on the upper end of the piston; the lower end being open to the air and the piston of the trunk type. In other words, our engine is single acting, with a power impulse or explosion every two revolutions—one revolution being required to draw in the charge and compress it; a second one to explode and expel the charge.

It will, therefore, be readily seen that when only one

cylinder is used, the application of power is at comparatively long intervals, necessitating a heavy balance wheel to keep up the momentum; and, even then, the engine must run at a high speed, or it is likely to be stalled in encountering any unusual resistance. To overcome this defect, more cylinders are necessary, to shorten the times of power impulses gauged in revolutions. Two cylinders will give us a power impulse at every revolution. Three cylinders, one at two-thirds of a revolution; four cylinders at each half revolution; six cylinders at each one-third revolution; eight at each one-quarter revolution.

While, therefore, we greatly improve the uniform application of power or the flexibility of the engine by a multiplicity of cylinders, we complicate our mechanism, making it more difficult to keep in order, so that a correct solution of the problem is not so easy as might at first glance be supposed. We are inclined to believe that the correct solution will have to be worked out by experience, and it is quite possible we have already reached it.

Broadly stated, the motor should be flexible enough to meet all ordinary conditions likely to arise, with the minimum number of cylinders. Many believe that the four-cylinder type comes under this heading, while others favor six cylinders and discourage the use of eight, maintaining that nothing "worth while" is gained by exceeding six. We believe that the four-cylinder vertical type is far in the lead at the present time, for cars of 20 horse-power and upwards. Experience may prove that the advantages of the six-cylinder type are more than balanced by its disadvantages, in which event the four-cylinder machine will continue to be the standard. Freedom from derangement, or dependability, and economy of up-keep are bound to be important factors with owners. This calls for simplicity of construction and fewness of parts, combined with best workmanship and materials.

Now, let us examine the air our horse breathes. Pure gasoline vapor is non-explosive. A light plunged into it will be extinguished. It must be mixed with oxygen or air to

become explosive. When five parts of vapor are mixed with one hundred parts of air it begins to explode, and we believe the most violent explosions are produced when about eleven parts vapor and one hundred parts air are combined. In an automobile this mixing is performed by the carburetor. When the piston descends the gasoline is drawn through a fine nozzle and sprayed into the mixing chamber, where it is rapidly vaporized and combined with the inrush of air. This air is generally heated by the escaping gases from the engine. Sometimes the carburetor is surrounded by a water jacket containing warm water from the cooling system; all of which tends to quicken the formation of gas from the liquid fuel.

It will be readily comprehended from what has been said that to get the maximum efficiency from our motor the mixture of gas and air must be just right. In that event complete combustion takes place, no carbon is deposited in the cylinders or escape pipes and no appreciable odor is detected in the exhaust. That is the ideal condition. Further, this condition may be closely approximated at one speed of the motor and widely departed from at another. The perfect carburetor is one which gives the ideal mixture at all speeds of the motor. By reading the advertisements of automobile manufacturers, you will find that *all* have provided their machines with perfect carburetor. Not one will admit of any imperfection. It is only after you have had experience in running a motor car that you begin to suspect that the truth has been considerably stretched and your faith in human nature gets another bump.

Now we have our mixture or charge in the cylinder ready to ignite, and the question arises as to the best means of doing it. The ignition problem cannot be said to be satisfactorily solved. It has received a great deal of attention, which is destined to continue for some time to come. The electric spark appears to be the neatest and most effective way of doing it. The best manner of producing the spark is still a subject of controversy. Two methods are in use—the make and break system and the jump spark system.

In the former the electric current is suddenly broken by some mechanical means, resulting in a spark at each interruption. In the latter the current is compelled to jump a gap of about 1-32 of an inch, producing a series or stream of sparks or fire. The latter is more commonly used, as it is asserted that the spark is more intense or hotter than that developed by the make and break method, resulting in a surer firing of the charge. It is vitally important that every charge be fired, since in a four-cylinder car, if only one cylinder is missing, one-fourth of the power is lost, without taking into account the power lost in compressing a useless charge.

Next, the manner of generating the electric current may be considered. Dry cell batteries were at one time very largely used. These are gradually giving way to storage batteries, the impression being that a hotter and better spark is produced thereby. The great objection to batteries is that they gradually become exhausted, the spark growing less intense, with consequent loss of power, by misfiring, and finally giving out altogether. This may occur where new batteries cannot be obtained, or the storage battery recharged. Gradually it is being recognized that a better arrangement is to make the motor self-contained and generate the current by the motor itself, through the introduction of a magneto, or dynamo. Magnetos have been brought to great perfection in the past few years, so that the best makes are both reliable and durable, and we believe are giving good satisfaction. With a dynamo the storage battery is kept continually charged, the current being generated as rapidly as used. Either of these systems should give a uniform spark, thus maintaining the continued efficiency of the motor and preventing fluctuations of power.

Timing the Explosion—It is evident that the explosion must occur when the piston is near the end of its stroke in the upward movement. In fact, when the motor first starts, the piston must be just about on its descent, the crank being over the center. The timer is a rotating piece of mechanism, with the points of contact corresponding with the number of

cylinders, each rotation of the timer giving a spark in each cylinder. This is operated by a lever from the steering column in close proximity to the steering wheel. A good arrangement is just above the steering wheel but the spark lever not turning with the wheel, so that its relative position is unchanged as regards the operator. The admission of gas to the motor is also arranged in a similar manner on the steering column, so that by moving a lever through an arc of approximately 180 degrees, the throttle is either closed or opened wide.

The power is communicated to the rear wheels through a clutch, transmission gear and differential gear. Two types of clutches are in general use—the cone friction clutch and the disc clutch. You are all familiar with these mechanical devices, so it is unnecessary to describe them. A good clutch is one which can be engaged gradually, and which will hold firmly when fully engaged. In starting, the engagement should be so gradual that the car moves off without a jerk. Disc clutches are undoubtedly an improvement over cone clutches in this respect, and the future will probably see them more extensively used. By means of the transmission gearing, the different speeds are realized, by shifting the gears. Most cars have three speeds forward, although some have four, and all have a reverse. The change speed lever is usually located on the side of the car, and when in neutral position no gears are engaged to propel the vehicle. On high speed the drive is direct through propeller shaft. The differential is an arrangement of gearing whereby the rear wheels move independently of each other. One wheel can stop or go in the opposite direction from the other. This is very important in turning. The principle is not new, having been used as early as 1843. However, there are many special forms of it which have been patented lately. Generally the axle is cut at the center, midway between the wheels and the gearing introduced at that point.

The steering mechanism usually consists of an inclined steering column with a wheel fourteen to eighteen inches in

diameter, mounted at the top, and a worm engaging a segment at the bottom, which moves an arm connected by a rod to the knuckle joints of the forward wheels, turning them about a vertical axis. The joints are so made that friction is reduced to a minimum, consequently the movement is effected with little muscular exertion when the car is in motion. Moreover the position of the wheels is easily maintained, as the toothed sector is rigidly held by the worm.

Comfort in riding is secured by good, flexible springs, pneumatic tires, fine upholstering and long wheel base. It is generally conceded that without pneumatic tires the great speeds attained by automobiles—90 to 100 miles per hour—could not obtain, as the chauffeur would be unable to remain in the carriage: what would become of the mechanism is left to the imagination. The tires readily absorb the small inequalities of the road surface with scarcely a jolt to the vehicle, while greatly lessening the shocks of the larger ones, making it easy for the springs to take care of them.

To prevent overheating of the cylinders two systems of cooling are in vogue—water and air. The former, by means of jackets surrounding the cylinders with water, which is continually circulated through effective radiators, these latter being cooled by the air passing through them when the car is in motion, aided by a fan. The former by greatly extending the cooling surfaces of the cylinders by fins or projections of various kinds and bringing powerful air currents against them by well designed fans.

Brakes—Most vehicles are provided with two sets of brakes—one on the propeller shaft and the other on the rear wheels, working on drums. Both sets are frequently placed on the rear wheels, one set being arranged to expand internally against the drum surface, and the other to contract and clutch the outer surface. Usually one set is worked by a pedal and the other by a hand lever at the side of the car. Or both sets may be operated by pedals.

Most clutches are now drawn into engagement by a powerful spring, so that the clutch is always in. In starting

the car the speed lever is placed in neutral position, the engine started and the clutch thrown out by the pedal and first speed gears engaged. After sufficient momentum is gained by the motor the clutch is gradually let into engagement. When the car attains the first speed the higher speeds are brought into play, the clutch being thrown out each time a speed gear is changed. From experiments performed in London it was demonstrated that automobiles running from three to about ten miles per hour could be stopped in much shorter distances than carriages drawn by horses. Where it took, say, twenty-five feet to stop the horses, the motor car used about fifteen.

Much more could be said about the electrical system, regarding the use of primary and secondary currents, spark coils with magnetic vibrators, spark-plugs, etc. A chapter could be written on lubrication and another on roller and ball bearings to reduce friction to the minimum. Still another on wheels and axles; but I think enough has been said to give you a rough idea of the modern gasoline automobile. The electric or the steam vehicle I have not touched upon. Both are extremely interesting and bound to divide attention with that described. Both have advantages over the gasoline; but perhaps, just now, the disadvantages more than outweigh the advantages. This would be a good topic for discussion at some future time, viz., "The Relative Merits of the Three Forms of Self-propelled Vehicles."

A word about prices. It has been said that the Automobile is a plaything for millionaires. It might have been at the start, but it has got beyond that now. The great usefulness of this Twentieth Century wonder is beginning to be generally recognized, so that its universal introduction is but a matter of comparatively short time. No doubt as the various types become standardized the cost of production will be lowered. Automobiles now at a dollar or two a pound are not so expensive as the electrical fixtures, "imported" glass (made in Pittsburgh), furniture, thermostats, or clocks in our new Capitol Building, if the newspapers can be believed, and

we get more value in the investment, not only in pleasure but in the intrinsic merits of the vehicle itself. Motor cars will never be cheap, in the common acceptation of that term, any more than locomotives. The best of materials and workmanship must be used to produce a satisfactory result.

The Automobile is here and we believe its staying qualities will be more manifest to all as the years go by. It will not prove a fleeting fad, like the bicycle, although there are many today who take this view. The two are not to be compared.

The pleasure of motoring, once acquired, will always remain. If you cannot go in your own car you will be glad to go in your neighbor's, especially if the train is late and you are anxious to get to your business. Your point of view will change immensely when you can take the chauffeur's seat and manipulate the levers. In such a position, on a bright spring morning, riding through the parks, with all nature aglow, you will think life worth living and consider yourself fortunate to be associated with men capable of creating a mechanism so perfect that twenty miles of beautiful scenery are made possible by the expenditure of one gallon of gasoline; and your wife and children will join with you in giving thanks.

(By Request.)

Automobile Transmissions.

BY E. H. BELDEN,*
Non-Member.

At the outset it will be necessary to give some definition of transmission, which is one of the most improperly applied words in connection with the automobile industry. It is understood to mean, generally, change-speed gearing. In other words, the change of ratio and direction of motion between the rear wheels and motor, but that mechanism is only one element in the train of devices, which transmits the

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power of the motor to the road wheels. So, therefore, we will designate the change-speed gearing as the "gear-set," and leave the word transmission with a broader meaning, to apply to the entire moving mechanism between the motor shaft and the road wheels.

The available energy, at the road wheels of the automobile, is transmitted from the engine through what is commonly known as a "transmission or gear set." The gear set may be one of many types, but in any case it must perform the office of changing the direction and ratio of motion, between the engine and road wheels, at the option of the operator. Means must be provided for the compensation of the relative motion between the driving axle and frame of the car, to allow for the use of suitable spring suspension, without interference to the uniform transmission of motion. Compensation must also be provided to allow one road wheel to operate independently of the other. Connecting and disconnecting of transmission devices, from the motor, must be accomplished in such a manner that the car may be set in motion without shocks, sudden jerks, or danger of stalling the motor.

Let us now leave out of consideration the advantages or disadvantages of any particular type of "gear set," to which we shall revert later, and take up the advantages and disadvantages of two methods, *i. e.*, the transmission of motion from engine to road wheels by chain and by propeller shaft.

CHAIN TYPE.

During the early days of automobile designing it was considered desirable by the majority of the best engineers to use the double chain drive, as shown in Fig. 1. The chain drive was considered to be the more flexible, because the spring action was not deadened by the use of the short propeller shaft, as shown in Fig. 2. The speed ratio could be easily changed by changing the size of the sprockets. It was considered to be the more efficient, because of the low efficiency of the bevel gears, when they were forced to transmit the enormous multiplied power of the larger engines. The

frame could be hung lower when the double chain drive was used, because the solid rear axle could be dropped the same as the front. In the double chain type of transmission all of the gears, including the bevel, were relieved of the greater strains on account of the ratio of the sprockets.

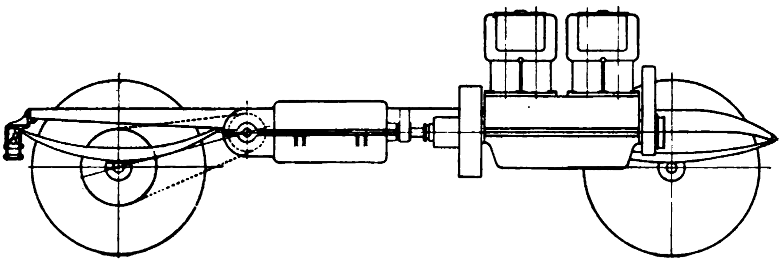


FIG. 1.

The principal disadvantages of the chain type are the constant stretching of the chain while the pitch of the sprockets remains the same, producing shocks and noise as the teeth come in contact with the chain rollers; the inability to provide suitable means for protecting the chain and sprockets from dust and mud; the excessive strain on the bearings of

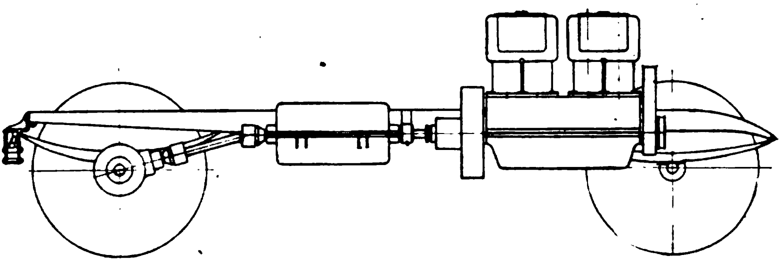


FIG. 2.

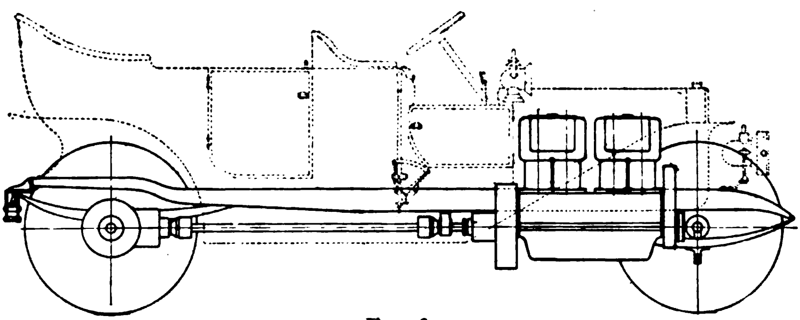
the road wheels caused by the pull of the chains, and the deadening effect on the springs caused by the angle of chains and distance rods. There are now being put upon the market three or four types of cars that are provided with cases to protect the chains. In each instance the construction of the chain cases are so unmechanical that there can be no doubt

but what the propeller shaft will soon antiquate the chain type.

The mere fact that the manufacturers of automobiles, with the double chain drive, are forced to provide their cars with chain casings that cannot possibly prove of advantage to this type of transmission, for the reason that they are only a makeshift, expensive to build, unmechanical, only partially dust-proof and subject to the danger of being totally destroyed every time the chain breaks, is sufficient proof that this type of transmission is far from the ideal.

PROPELLER SHAFT TYPE.

Now that the trend of automobile designing has been constantly away from the chain types, we must admit that the



FIG, 3.

bevel gears have been perfected, both in material and design, to such a degree that their efficiency and durability is equal to that of the chain type when operated under road conditions. Bevels can be changed to alter the ratio as readily as changing the sprockets and the lengthening or shortening of chains. The matter of lowering the frame has been taken care of by the use of a drop frame, as shown in Figs. 3, 4, 5, instead of a drop axle. The propeller shaft transmission has an advantage over the chain type of being completely enclosed, protected against dust and mud and always well lubri-

cated. This enclosed transmission maintains constant efficiency and is practically noiseless.

The sliding "gear set," as shown in Figs. 6, 7, 8, has an average efficiency of about 78%. The "transmission" effi-

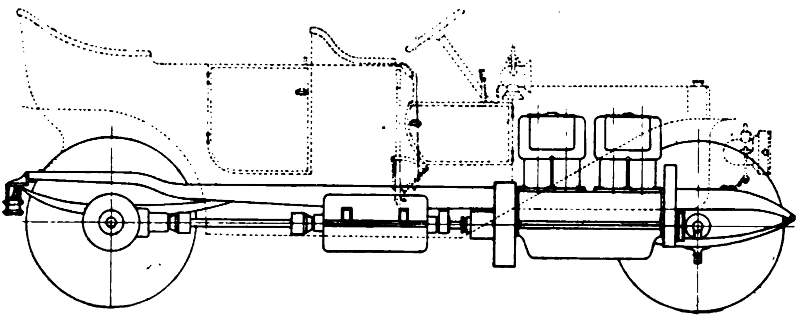


FIG. 4.

ciency (*i. e.*, the efficiency of all moving mechanism between the motor and wheels, including cardan joints), with the gear set between the propeller shaft and motor, as shown in Fig. 2, has an average efficiency of about 67%, while the average transmission efficiency of the more modern car, using the

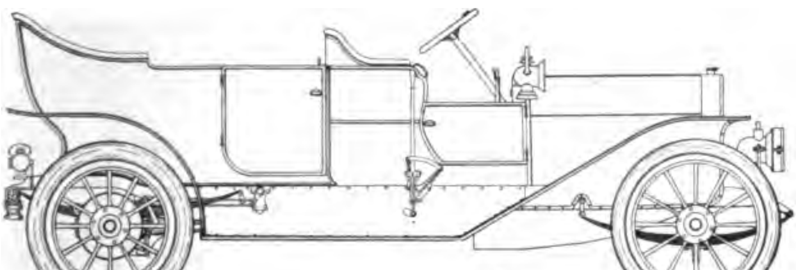


FIG. 5.

propeller shaft type, with the transmission in the rear axle, with no multiplied power in the cardan joints, is 88%. The transmission efficiency of the "Belden system," with no multiplied power in either the cardan joints or bevel gears, as shown in Fig. 4, is 98%.

After comparing carefully a number of efficiency tests on both the chain and propeller shaft types, we find that the chain type, when the chains are new, clean and well oiled, has about 10% more efficiency than the propeller shaft type when

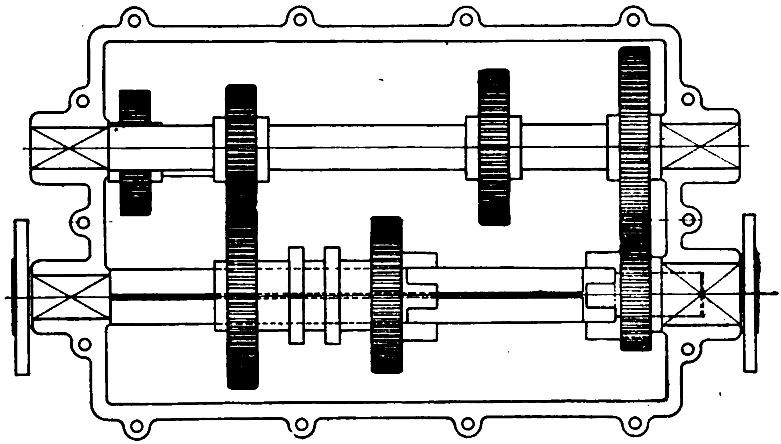


FIG. 6.

the shaft is placed at a great angle and forced to transmit the multiplied power of the gear set. But comparing the chains on modern cars under ordinary working conditions, with the chains exposed to mud and dust, as they usually are,

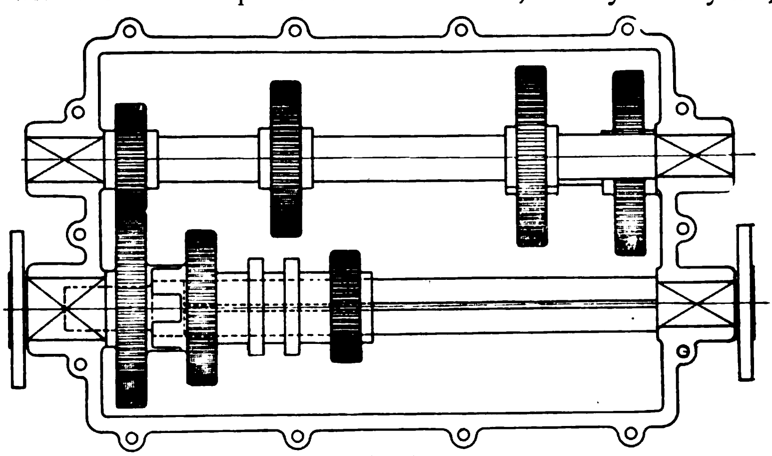


FIG. 7.

and the propeller shaft type with the transmission in the rear axle, thereby eliminating the great angle of the shaft and the multiplied power in same, we find the efficiency decidedly in favor of the latter type.

POWER LOSS.

Engineers are agreed that the greater part of power loss of the transmission of motion in automobiles is in the propeller shaft and cardan joints, due altogether to the friction

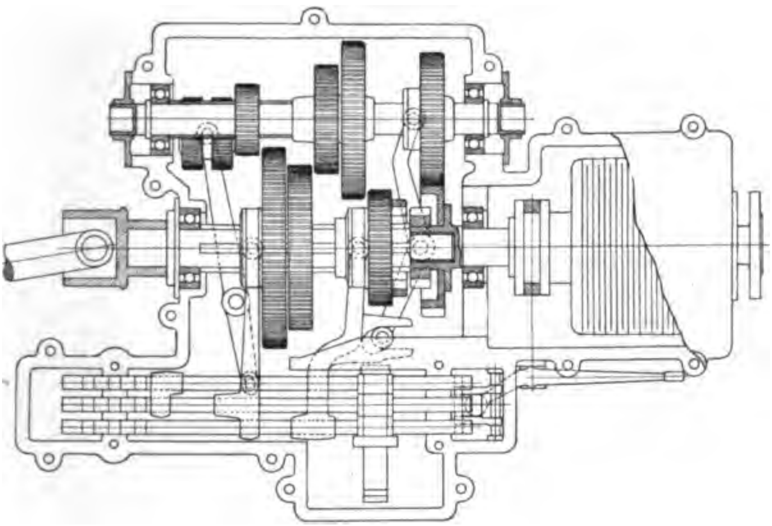


FIG. 8.

of the cardan joints when transmitting power at a great angle, as shown in Fig. 2.

Now, considering the fact that bevel gears are inefficient when under excessive strains, we must come to but one conclusion. The automobile of the future will be built on the lines of the car shown in Figs. 1-5, with the motor set back of the front axle. With the motor shaft in line with the rear axle (which will eliminate all loss of power in cardan joints); with large wheels to increase road clearance and decrease

road shocks, as well as road resistance; with drop frame for the purpose of keeping the center of gravity low.

With "gear set" placed in the rear axle, for the following reasons:

First. To eliminate the transmitting of the multiplied power of the gear set through the propeller shaft and cardan joints.

Second. To allow sufficient road clearance midway between the front and rear axles, which could not be possible if the gear set is placed under the body, as shown in Fig. 3.

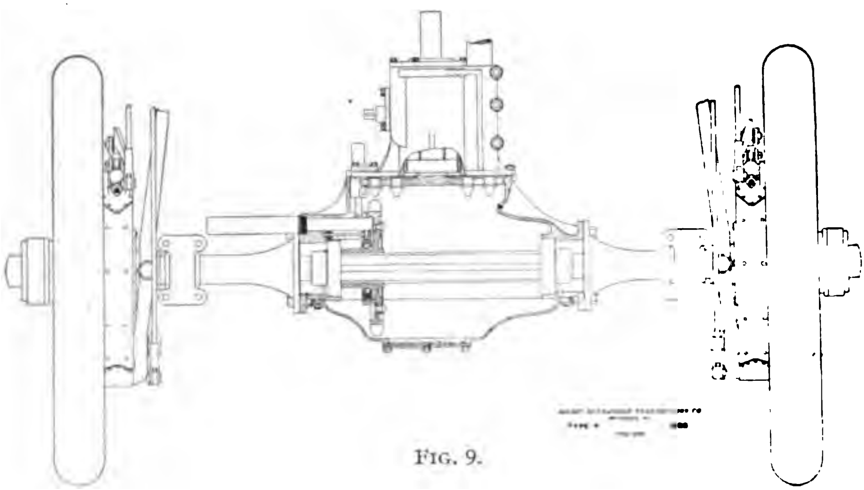


FIG. 9.

Third. So that the multiplied power will not pass through the bevel gears but pass through more efficient gears, as arranged in the Belden type of transmission, shown in Fig. 11, thereby eliminating the inefficiency of the bevels.

We will now take up the following types of gear sets:

Electric—Hydraulic—Planetary—Friction—Individual Clutch—Sliding Gear, Progressive Type—Sliding Gear, Selective Type—Belden.

Much can be said both in favor of and against many of the above types, but I will only refer to the more important points.

While it is very important to design a "gear set" to operate perfectly, it is equally important that it shall be designed to suit the whole train of transmission. In other words, no matter how efficient a "gear set" may be, little is gained if it is installed in a position that will lessen the efficiency of the whole transmission of motion between the motor and rear wheels.

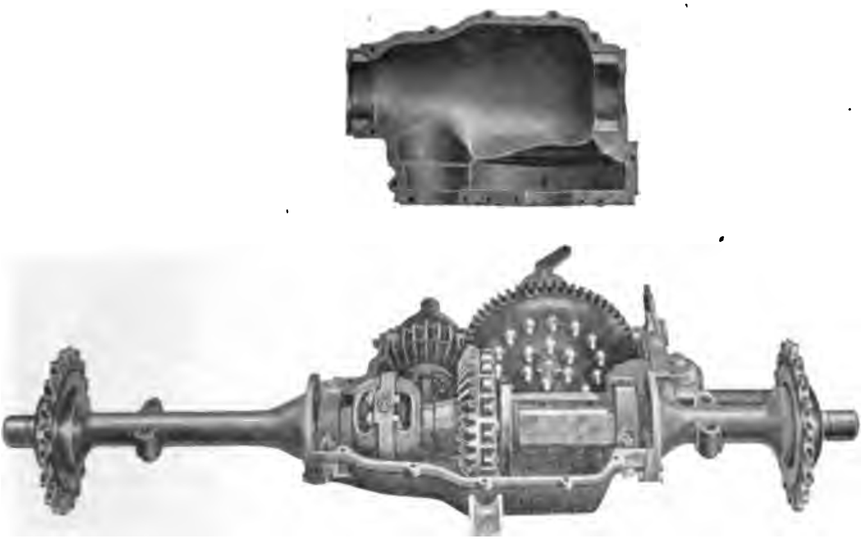


FIG. 10.

ELECTRIC.

The idea of utilizing the power of the combustion motor to generate the electric current which was converted into mechanical power through the medium of an electric motor has been one that has appealed to investigators, and many systems have been devised, the majority of them involving the use of the storage battery, while the location of the motor is varied, being placed at the wheels in some cases and directly behind the generator in others, a mechanical connection being employed in driving on high speed in the latter case.

In other words, the fly-wheel of the ordinary combustion

motor has been displaced by the generator, which is direct connected to the crankshaft of the motor. In other respects the motor is of the standard four-cylinder type. Immediately behind the generator an electric motor is placed, though there is no mechanical connection between the two on any but the high speeds, when the crank-shaft of the motor and propeller-shaft terminating at the live rear axle becomes solidly coupled and both the dynamo and motor run dead. The low speeds are used in starting, the motor being capable of heavy overloads and when up to speed a clutch is employed to couple

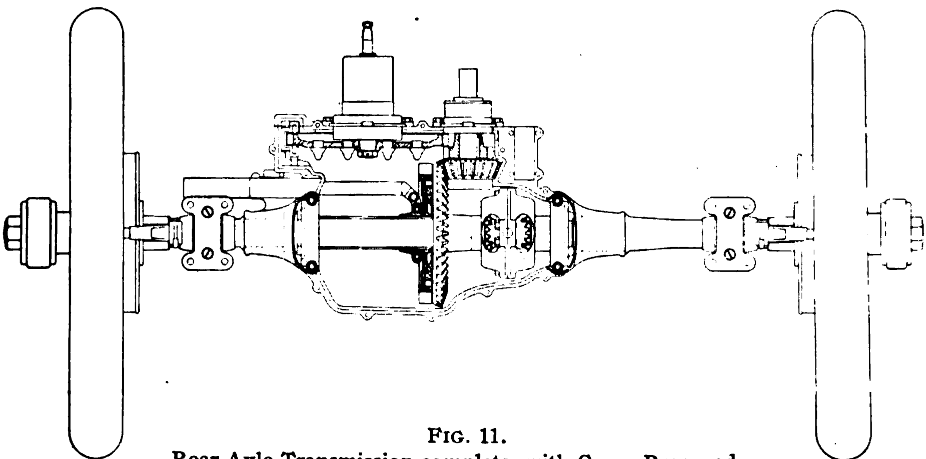


FIG. 11.
Rear Axle Transmission complete, with Cover Removed.

the motor and propeller shafts, and the car runs exactly the same as when equipped with the usual change speed gear. This system is only in an experimental state, so that little can be said in its favor. If the weight, cost of construction and maintenance can be kept low enough to make it compare with the ordinary gear set, it will be a transmission that will meet with much favor.

HYDRAULIC.

In a so-called hydraulic transmission recently produced there is attached to the motor flywheel a rotary pump capable of pumping oil at a pressure of 2½ tons per square inch. The

oil flows under pressure through a tube to the live rear axle, on which is mounted another rotary pump, which is driven by oil and acts as a turbine, turning the driving wheels of the car. Dividing the turbine into halves does away with the differential, variation of relative speed of the driving wheels being balanced by the oil following the path of least resistance. The oil returns to the first pump. The speed of the car is controlled by allowing more or less oil under pressure to reach the turbine. Reversing the turbine reverses the motion of the car. Shutting the cock controlling the "power" oil and also that controlling the "exhaust" oil, to imprison the oil in the "inlet and exhaust" pipes, stopping the revolving of the turbine vanes, constitutes the brake.

PLANETARY.

The planetary gear set when installed in light cars with comparative high-power motors, where only two speeds forward and reverse are necessary, has always been recognized as the ideal change-gear system. It consists of groups of gears carried on the adjoining end of divided shafts and on a floating plate, the gears being in mesh all the time. It is very efficient on high speed when the entire gear-set is revolving with the motor shaft as one piece. The annoyance of much noise and the necessity of a very low ratio on first speed and reverse (on account of inefficiency) has been put up with by many, because of its low cost of construction, ease of operation and efficiency on direct drive.

Three-speed planetary gear-sets have been attempted, but with very unsatisfactory results, else they would be in general use to-day. When either the reverse, the low or intermediate trains of gears are in service, the gearing on the other two speeds is in action, consequently offsetting the advantage of the intermediate speed.

FRICTION.

Friction transmission consists essentially of driving and driven friction discs. The edge of the driven disc rolls on the face of the driving disc and has a movement crosswise.

The nearer it moves to the center, the slower it will rotate. When moved across the central point the direction of rotation will be reversed. A considerable number of speeds can be obtained by this method. Theoretically it is the ideal type of transmission. Commercially nothing can be said in its favor. Much money has been spent in endeavoring to perfect this system to such a degree that it would be a commercial success. The mere fact that it is not in general use is sufficient evidence that it cannot be worked economically in connection with the combustion motor. A very narrow face on the driven disc is necessary to minimize the wiping friction of the driving disc as much as possible, which makes the point of contact between the two friction discs limited to such an extent that there is a slippage at the time of each explosion in the cylinder, causing enormous loss of power, because of a limited amount of expansion in this type of motor. This one objection is sufficient to make the friction drive anything but a commercial article. There is, however, a transmission, known as gearless, that is worthy of mention, because of its being direct on high speed.

INDIVIDUAL CLUTCH.

The "individual clutch" gear-set consists of two or more parallel shafts, on which are mounted gears of different ratios similar to the ordinary sliding "gear-set." The gears are always in mesh and always in motion. Each pair of gears is provided with a separate clutch. Much can be said in favor of this type of "gear-set" because of its ease of operation. The change of ratio and direction is obtained by disengaging one clutch and engaging another, without danger of stripping the gears. It has, however, many drawbacks. The clutches are necessarily small and require very close adjustment. If they are adjusted close enough to hold without slipping, they become heated and work against each other when expanded, hence the inefficiency, necessity of frequent adjustments and complication of parts, have been the principal causes of its unpopularity.

SLIDING GEAR.

In the sliding gear transmission there are two types, the progressive, shown in Figs. 6, 7, and the selective, shown in Fig. 8. There are many subdivisions of these types, but the broad features are the same in all.

They are constructed with two or more parallel shafts, each carrying gears of different diameters. The gears on one shaft can be slid along, into and out of mesh with the gears of the other shaft, thus forming different combinations as the gears are brought together.

The progressive type has the advantage of simplicity and the disadvantage of having to slide through one gear to get to the other. While the selective type is more complicated, the ratio and direction of motion can be changed without passing through other gears. The trend of the trade is now decidedly for this more complicated type to avoid as much gear-stripping as possible.

In my opinion a four-speed transmission is not necessary as far as the control of the car is concerned. It does, however, minimize the dangers of stripping when the sliding gear-set is used. In other words, it requires one more operation to go from low to high speed, which, of course, is easier on the gears, *i. e.*, the grinding on the edge of the teeth is divided among four gears instead of three.

In Fig. 6 is shown a progressive type of gear-set with the gears arranged so that the countershaft rotates slower than the motor shaft.

In Fig. 7 is shown another progressive type with the gears arranged so that the countershaft rotates faster than the motor shaft.

In Fig. 8 is shown a selective type of gear set, with an automatic attachment to throw the countershaft out of action when running on high speed.

I know of no better way to illustrate the inconsistency of the "so-called" good designing of automobiles than to call particular attention to the above Figs. 6, 7, 8.

THE BELDEN.

In Fig. 9 is shown the simple type of the Belden gear-set, and rear axle. This axle was used on three of the 110 horse-power Vanderbilt Cup racing cars. The standard gear-sets of the 24 horse-power type were used. The housing was cast aluminum without truss rods or braces of any kind. They stood up through the race and all the testing out, without accident, or the slightest adjustment. They operated without the slightest noise at a speed of 100 miles per hour and were shifted from one speed to another without releasing the clutch or the aid of any interlocking device.

In Fig. 10 is shown the Belden standard 60 horse-power chain type of gear set, three speeds forward and reverse.

In Fig. 11 is shown the Belden standard 60 horse-power rear axle, three speeds forward and reverse.

Instead of the bewildering assortment of gears, such as adorn most automobiles, the Belden system of transmission and control furnishes a simplified apparatus consisting of two gears in the rear axle and is controlled by the movement of one lever at the side of the operator. It is a positive drive direct on all speeds, and when installed in a car of the type shown in Figs. 1-5 delivers 98% of the power of the motor to the rear wheels, this result being obtained by the rolling contact between the two gears, which form the principal part of the transmission, and by the absence of angularity of the propeller shaft and the multiplied power through the bevel gears. The Belden gear differs from other gears inasmuch as it has a rolling contact with teeth inversely and obversely curved. It is noiseless and operates without friction. It has the advantages of the friction type without the loss of power by slippage, as it is a positive gear-drive. It has all the advantages of the planetary system and none of its disadvantages, as there are no gears in operation on high speed and is direct drive on the other speeds. It also has the advantages of the selective type of transmission and none of its disadvantages, *i. e.*, it is shifted from one ratio to another without passing through gears and does not possess its complications.

It has the advantages of the hydraulic and electric transmissions because of its being absolutely noiseless, and has none of the objectionable features of other types of transmissions because of their complications, inefficiency, noise, unsightly appearance, etc.

(BY REQUEST.)

Automobile Tires.

BY H. W. DU PUY,*
Non-Member.

The pneumatic tire was undoubtedly the most important invention which had to do with the development of the automobile, for without it the touring-car as at present used for pleasure purposes would not have been a possibility. The reason for this is not so much that the pneumatic tire gives comfortable riding qualities to the car, as that by its absorption of the small inequalities of the road-surface it saves the motor and mechanism from an enormous amount of vibration. The question might be asked as to whether solid rubber tires would not serve as well for use in districts where the road-surfaces were comparatively smooth. They can be used satisfactorily up to a speed of fifteen miles an hour, but beyond that they are impracticable, no matter how smooth the road.

It is a well-known fact that if an object is allowed to drop in the air, after it has attained a certain speed the resistance of the air will equal the acceleration due to the force of gravity, so that the speed of the object will not increase beyond a certain limit. The drag of solid tires against the force of the motor acts somewhat in the same way; the higher the speed the greater the power necessary to lift the wheels over the small inequalities of road-surface until finally a limit of speed is reached at which all of the power is consumed. This limit is comparatively low. By experiment it has been found to be practically impossible to drive a car faster than twenty-five miles an hour on solid tires, even by using engines of very

* Of the Pennsylvania Rubber Co., Jeannette, Pa.

high power; this would certainly not suit the modern motorist: but of much greater moment than the reduction in speed would be the racking of his nerves and the wear and tear to which the mechanism of the car would be subjected.

Many attempts have been made to imitate the action of the pneumatic tire by the use of spring wheels, pneumatic hubs, etc., but up to the present time with indifferent success. While these devices take up the vibrations transmitted to the wheel to a certain extent, they do not provide a cushion at the place where it will be most effective, viz.: in contact with the road. They act as delicate springs in decreasing the force of shocks borne by the wheel, but do not *absorb* these shocks as does the pneumatic tire. Inequalities and small obstacles sink into the tire so that the wheel does not require an extra amount of power to lift it over them. For this reason it is very doubtful whether a practical substitute for the pneumatic tire will ever be discovered.

With the phenomenal increase in the production of automobiles during the past six years, there has been a like increase in the output of the tire manufacturers, so that the available rubber supply of the world has been seriously affected; imports of crude rubber into the United States alone last year amounted to $50,000,000, a considerable proportion of which was employed in the manufacture of tires.

The rubber factory which undertakes the manufacture of automobile tires requires an elaborate and expensive equipment, consisting of washing machines for the crude rubber, mixing mills for combining the rubber with sulphur, zinc, litharge and other ingredients which influence the vulcanizing process and serve to give strength and wearing qualities to the finished tire. Huge calender rolls are required to roll the rubber into sheets of the proper thickness to be used in building up the tire. Whole rows of great hydraulic presses heated by steam are used for vulcanizing the tires after they have been placed in the molds. The number of the latter which must be kept on hand depends only on the demand for tires of each size and type.

Before being placed in the mold the tire is built up by hand on an iron form. The layers of fabric coated with rubber are laid on, first of all being drawn tight over the tread, and worked down over the "bead." When the plies of fabric are in position and rolled smooth a sheet of rubber is laid on to form the cover. If the tire is to have a molded tread the latter is formed by being built up of layers of rubber to the proper thickness. If a "wrapped tread" is to be put on, the tire is molded with only the cover in place, and, after being removed from the mold, has the tread wrapped upon it with cloth, and vulcanized.

Tires should be allowed to age for a certain length of time before being put into use. During this time they "bloom," that is, become light gray in color, due to the action of the light acting on the active chemicals in the rubber.

DISCUSSION.

The President: Gentlemen, the paper is now open for discussion. We will be glad to hear from any of you on any of the points brought up in the papers, and some that have not been touched upon. We would be glad to hear from Mr. Trinks.

W. Trinks: Gentlemen: I did not wish to be the first man in the discussion, but since Mr. Kintner asks me, let it be so. I think that Mr. Belden's device is indeed very ingenious, but I would like to take a stand against one point, and that is the perfect rolling contact of gears. I was taught and I teach it now, that there is no such thing as perfect rolling contact between toothed gears, that gears, in whatever shape they may be, must show sliding except at the point of contact of the two rolling pitch circles. Now gear teeth cannot touch at that point all the time; they approach this point, while in contact, and after passing through it, recede while still in contact. There is sliding and friction, and it must be directly proportional to the distance of the tooth contact point from the pitch-circle-contact point. If Mr. Belden can invent a gear

in which there is rolling contact between the teeth, I think he is the greatest engineer of this century. I certainly would like to know how he does it. I believe that there is a very common misunderstanding among engineers, a wrong idea that gear teeth which are correctly designed have rolling contact. The rolling contact is between the pitch circles, but not between the gear teeth. It is a very common belief, but at the same time, it is wrong, it is a mistake, and I think it should be cleared up.

Mr. Belden: The gear itself is exactly opposite to all standard gears. The patent we secured on it has a very broad claim. It merely covers a gear with one tooth inversely and the other obversely curved. And that is sufficient evidence to prove that no one up to this time had ever attempted to patent a gear of that construction. The teeth in the disc rotating at right angles to (what we call) the two pitch gear on the main driving shaft rolls in at a peculiar angle. The gear was not generated or cut by any scientific methods, it was simply hewed out with the experimental work. While to the eye it might not appear to be a perfect rolling contact, at the time it is rolling in similar to an ordinary spur gear, it is also rolling in a cross direction, so that the point of contact is changing in every position it is in, preventing the cross slide. To show that there is no cross slide: The axle shown in Fig. 9 was used in the 110-horse power racing car (and as I drove one of the cars myself I could fully appreciate the amount of strain that was put on those gears in turning the corners), sliding from one speed to the other without releasing the clutch, and in the shifting bar that holds the side thrust of the two pitch gear there is only a small 3-16 inch screw that does the shifting of the gear, and those screws, one at the top and one at the bottom, are sufficient to take care of the side thrust on a gear in transmitting the enormous power that was transmitted through the gear in that race. In one of the cars that was run three months before the race and traveled 8,000 miles, the gear today shows practically no wear. Of course, we use high-grade chrome nickel steel in the gears. We have made a number of

tests running the gear without oil for a long period, without showing any particular wear. Andthe fact that a gear of that size—and some say it only has a point contact—will transmit 110-horse power at 100 miles an hour, at times; and an average of 70 miles an hour for 8,000 miles, without showing wear, is fairly good proof that it is nearly a perfect working gear.

The President: Is Mr. Kent Smith present? We would be very glad to hear from him in regard to special steels suitable for automobile construction.

J. Kent Smith, Non-Member: I am obliged to you for the courtesy which you have extended to me in inviting me to be present to-night to hear the various interesting papers I have listened to, all dealing with a subject that has a great deal of interest to me.

The requirements of engineering to-day are very different from what they were a decade or two ago. The steel-maker has risen to the occasion, and he has perfected enormously the materials which are at the disposal of the engineer. I say advisedly that of all the mechanical applications to which steel is put to-day there is no application which has tended so much to the advancement of quality in steel as the automobile industry. I think that has done more than anything else for special steel, in bringing out points which have put the steel-maker "on his mettle," so to speak, and which he has been able to fill to a large extent. The automobile can admittedly exist only on the very best class of material. And our notions of steel to-day are somewhat different from what they were some years ago. The steels which were at our disposal fifteen or twenty years ago were excellent of their kind, but they were not sufficiently excellent for the purposes of the modern engineer. Modern engineering requirements raised points which had to be threshed out and which have finally been met.

Speaking more especially of the special applications of steel I think it is admitted that steel makers misled themselves as to "improving" steel. We used to judge steel almost entirely by its behavior under static stresses; that is, under steadily applied loads. Now we have to go much farther.

We used to think that because steel would do certain things under steadily applied pressure, that it would do pretty much the same kind of things where the stresses were totally differently applied; but in many instances we began very soon to realize our mistake. The gasoline engine imposes very different requirements on the materials composing it from the old engine, which made one revolution once in a while and where weight did not much matter. We must have something which is strong, is light, and most important of all, *remains* good. The test of strength is the elastic strength of the metal and not its ultimate strength. That static ductility is necessary goes without saying.

But we have got to think of other points. If the strains in a gasoline engine were carefully analyzed it would be found that nearly 90% of those strains are applied dynamically and a little over 10% statically. It is not common sense to judge the material carefully on the 10% requirement and let the other ninety per cent. take care of itself and trust to luck.

Dynamic requirements are typified in the highest degree in automobile construction. That is to say, a steel which is good enough for a given part of an automobile is good enough for anything else in that line. A steel that will make an automobile axle will make any other axle under the sun, and so on.

But we have got so many things to consider. If we are going to make an automobile crank shaft, or judge a steel fit for that purpose we have not only to consider rigidity and strength of the material, we have also got to take into consideration torque, resistance to repeated impacts, which are very considerable, and to vibration. In a four-cylinder engine we have two impacts every revolution and over one thousand every minute. Thus we have to consider the vibratory molecular deterioration of the steel and we have got to judge as far as possible what the shaft is likely to be after it has worked some considerable time under all the peculiar difficulties it has to encounter. In other words to improve that steel we have not only to improve it from a static point of view, but we have got to endow that metal with life, and that

is where the steel specialist to-day comes in, especially in the line of automobile construction. Then there is the additional consideration of wearing surface. Do not think that I want to underrate the value of static tests, but we must not deceive ourselves. We must not strain after something *we do not want* beyond a certain point if incidentally we have to sacrifice something which *we do want*. There is no use in doubling static strength, if we are going to almost entirely sacrifice dynamic superiority, which we want because we must have metal to resist deterioration *under work*, as far as possible. I have worked with engineers in Great Britain for a long time with special reference to steels for use in automobile construction. We have got so many different classes of steel typified in the motor car, and such an infinite number of different points to consider, that it behooves us to dive into the steel subject very deeply.

The metal Vanadium is the only alloy which gives dynamic superiority to steel. It is also a static intensifier; that is, it intensifies the strengthening power of other alloys, which if exclusively used in such proportion as to considerably increase the static strength almost invariably "poison" the metal from a dynamic point of view. By making use of the two actions of vanadium on steel, that is, the power of static intensification, thus using so small a proportion of the other alloy as to not seriously injure the dynamic properties of the steel, and taking advantage of vanadium conferring dynamic qualities to steel, we get a combination which we cannot possibly get by any other means. By selecting different tests and testing steel on lines somewhat analagous to requirements in practical life, we get nearer to the correct conclusion than myriads of years of testing under the old systems could give us; and I would reiterate my former remark, that in my opinion to the automobile more than to anything else is attributable the great stride forward which steel has made during the past eight or ten years.

The President: I judge Mr. Beutner is an automobile

enthusiast, as I have not seen him here for years before, and we would like to hear from him.

Victor Beutner: The most troublesome part of a gasoline motor has hardly been mentioned to-night. An immense amount of thought has been given to the perfection of transmission systems. Ignition has been very much perfected, and the modern methods of high tension spark generation and single coil distribution are very ingenious indeed. The remarkably crude point of the automobile is the carburetor. Even the best of the modern high-priced carburetors give but a very poor mixture, due mainly to the fact that in vaporizing gasoline by passing an air current over a spray nozzle, the quantity of the air has no direct relation to the amount of gasoline vaporized. This amount is determined by the velocity of the air and is nearly proportionate to the square of this velocity. So far no suitable instrument has been devised which vaporizes gasoline in a positive proportion to the square of the velocity, at which the air forming the proper explosive mixture with the gasoline vapor is drawn over the spray nozzle into the cylinders of the engines. The aperture being the same, this velocity varies of course with the amount of explosive mixture required to fill the cylinders at various speeds. All modern carburetors rely upon an auxiliary spring check-valve, which is lifted automatically as the suction increases with the engine speed and thus admits additional air to thin out the explosion mixture, which at the higher speeds is too rich. Now ninety per cent. of all gasoline engine troubles result from a faulty mixture and the fouling of sparking plugs incidental therewith. Here is a beautiful field for somebody to get up something mechanically correct.

A great hobby of mine has been passed over to-night with scant attention, that is the two-cycle, or better, the two-stroke, engine. The two-stroke engine for units of moderate size and high speeds is the coming thing and will certainly show wonderful results if it receives in the next few years the same amount of thought as the four-stroke engine has recently. I suppose the principle of the two-stroke engine and all the

hackneyed arguments for and against it as to simplicity, unreliability, higher operating cost, etc., are well known to you. One element which would not strike one as of prime importance at the first glance is only lately receiving the attention which it deserves. That is the high velocity with which the explosive mixture and the exhaust gases travel and the momentum acquired by them in both directions. The future success of the two-stroke engine will depend greatly upon a closer study of this momentum and of means by which it can be utilized for sweeping out the spent gases and obtaining practically a full charge of new mixture. This cannot be done in a four-stroke engine even with opposed inlet and outlet valves. Interesting experiments have been made by inserting a fan into the exhaust pipe which revolves with great velocity, due to the sharp impetus received from the outflowing gases at the first opening of the exhaust port and keeps them moving at the later period of the stroke. Neither the three-port nor the two-port check-valve principle is correct, but the admission of the mixture into the crank case must be regulated by a positive motion valve, operated by a cam or by a rotating disc-valve attached to the crank.

Mr. Trinks: In the paper of the evening one more point ought to have been mentioned, and that is the problem of indicating these high-speed engines. If you have ever tried to take indicator cards you know that you are all right with almost any indicator when you have to deal with 100 or 200 revolutions per minute; you begin to think harder about the problem when you have 300 revolutions; but when you have to go beyond 400 R.P.M. you look all over the country to find an indicator that will do the work. The makers say that it might work, but the inertia of the indicator parts is so great that you will not get any results, and if you should get results, they are far from right. Now what will you do with the 1,000 or 1,200 R.P.M. of the automobile engine? While I have never personally examined one, I have heard and read about a suitable indicator, and I certainly hope that our schools will later on buy one for the laboratory. I mean

the optical indicator. The principle is that a small mirror is tilted in one direction by the motion of the plunger or piston. It is tilted at right angles to this motion by the deflections of a small diaphragm, acted upon by the pressure of the explosion. All these parts are so light that there is practically no inertia and no friction resistance. There being no pencil, but only a beam of light, you have to photograph it. The beam is thrown against a film or a gelatine plate and its motion is thus photographed. To my knowledge this indicator is the only one which has given satisfactory results on high-speed gasoline engines.

The President: Electrical engineers make use of a device somewhat similar to that mentioned by Prof. Trinks, known as an oscillograph, in which the wave form of alternating currents of electricity are determined. Frequencies of 1,000 per second can be observed. Variations in the wave form of five or six per cent. can be very accurately determined.

There are several points that have not been mentioned, particularly the point of lubrication.

Mr. Garlinghouse: With regard to lubrication, it is a pretty nice problem to get just enough oil into your engine. Of course there are a great many kinds of mechanical lubricators, but the trouble seems to be to get just enough. If you get too much it will carburize and get on your spark plugs, etc. Understand, too, you have got to use the right kind of oil. But these things have been improved very greatly in the last two years, so that the lubrication of machines is generally pretty good.

The President: It may be that the automobile lubricant that is continuously leaking out will solve the problem of dust settling, judging from the amount seen leaking from the majority of machines. In the New York Subway one of the early possible difficulties was with dust, and it was proposed to settle that dust with oil. Since that time they have been adopting every precaution possible to prevent leakage and to collect the oil that is falling out on the track, the dust not being as serious as the smell of the oil.

Mr. Beutner: One feature shown at the automobile show in New York was of interest to engineers. It is remarkable that practically no radical improvement has been made during the last six or seven years over the well-established design of the four-stroke engine—that is, of the engine proper. Better materials and better proportions are in evidence, but the type is the same. One of the exhibits, however, showed a rotary valve with ports for admission and exhaust suitably located and the whole thing water cooled. This idea looks good to me, and if it shows good practical results in actual operation it ought to revolutionize gasoline engine design. Imagine one single rotary valve, rotating at one-half the speed of the crank-shaft, instead of the mass of cams, springs, puppet valves jumping up and down at high speed in a multi-cylinder engine!

E. K. Morse: I would like to ask if the tendency of the present makers is for the water-cooled machines or for the air-cooled, and the reason why?

Recently there has been a good deal of discussion, especially in the Eastern papers, regarding the effect of automobile travel on the pike roads. It is claimed that the suction of the tires and the rapid movement of the automobiles are responsible for the removal, in the shape of dust, which floats away; of the finer portions of the top dressing, which are essential for the bonding or cohesion of the wearing surface of macadamized roads; also that the suction of the tires has a tendency to make the top dressing of the roads spongy, or as they term it "shredded." We have with us this evening an engineer of the Good Roads Department of Allegheny County and I should like to hear from him regarding this.

Geo. T. Barnsley, Vice President: Mr. President, I have heard through the newspapers and other sources of the great damage the automobile is doing or is going to do to the macadamized roads. I must say for the sake of the automobile people that I cannot see very much damage to the improved roads due to the Automobile. In the first place the law of Pennsylvania provides a twenty-mile limit for speed;

when officers are not looking they sometimes go faster. So far as the raising of dust is concerned, I have hundreds of times seen great clouds of dust raised by vehicles on an ordinary road in a funeral procession. It is true that the rubber tire does produce a suction. As to the practical amount of damage done at a high rate of speed, I am not prepared to say because I have not inquired into it far enough.

The matter that has interested me most in the wearing of our roads is the question of the width of the steel tire on vehicles carrying heavy loads: narrow tires with their sharp edges create a great deal of abrasion and of course wear the surface of the road and grind the material to powder, which is carried away by the winds or heavy rain. To overcome that I have given a good deal of thought as to the best method of holding it. I might say for the benefit of you Pittsburgh gentlemen that I hope to make some experiments this year that will show us the most economical way of holding that powder on the road, thereby retaining the use of it as a cushion. In other words to make the top dressing become in the nature of an asphalt surface. I think that the question of the wear and tear by fast speeding of the automobile will be something that we will be able to discuss from a practical standpoint later. At the present time the other troubles have engrossed my attention. I know from practical experience that the other troubles produce more serious results than the few people who drive automobiles at a great speed. This high speed is only indulged in by a few people and I think it is a great mistake to try to evolve the idea that great damage is due to high speeding resulting, as some think, in the rapid wearing out of the road. I think it is a great mistake because the automobile is a machine that is being developed and made more useful every year. It is practical; it has come to stay; it has great commercial possibilities. I would rather that the brain power should be given to the good that the automobile is doing and is going to do, rather than to the supposed danger.

The President: There was another point raised as to the preference in the manner of cooling.

Mr. Garlinghouse: That is a pretty hard question to answer at the present time. People that run air-cooled cars think that system is the best; those that run water-cooled think that is the best. Of course you can see this in regard to air-cooled cars, that they have no pumps and no water to freeze in the winter, and those are desirable things to eliminate. On the other hand you use a good deal more oil and I think create a good deal more odor and smoke from an air-cooled car.

I would like to go back to that road question once more. Out on the plank road that I go over a good deal in summer there was an experimental track with steel ribbons about six inches wide with a small bead on the outside. It did not stay there very long—probably two years. The trouble with that was mainly that wagons would not stay on it but would drop off on either side and consequently we soon had deep ruts running along the sides of those ribbons. If only automobiles ran over that road that never would have happened. It would have been in practically the same condition it was when those steel rails were put down. That would show very plainly that the automobile is not nearly so severe on the road as are ordinary vehicles. And moreover, this statement is confirmed in running over a field or grass plot. For instance, take a piece of my lawn that I have been running over for two years; the grass continues to grow and is not worn at all. If you had a carriage going over there, in three days' time it would be all cut up, both with the wheels and the horses' hoofs.

Mr. Barnsley: I am very glad Mr. Garlinghouse has brought out that point. It is only fair to himself that he should bring it out. I have never yet seen an automobile do any rutting; all other vehicles do that on the road more or less; that is the tendency. They will powder up the top surface: it blows away and washes away; and yet some of our people are so much afraid that the automobile will suck all the material up and get rid of it that way!

I simply want to emphasize the fact that I think there is rather an undue effort on the part of many who do not understand the question in a practical way, when they theorize and talk about the danger of wearing away the road by the excessive use of the automobile. I am not at all in sympathy with that.

F. C. Phillips: I would like to ask whether it is possible to produce the explosive effect in one of these machines without the violent shock?

Mr. Beutner: The greatest safeguard against the initial shock of the explosion is the high piston velocity of the modern gasoline engine. Even with ignition taking place practically instantaneous, the piston moving away at a speed of 1,200 feet per minute cushions this shock considerably and I have not heard of serious trouble resulting from this source.

CORRESPONDENCE.

The following paper by Wm. P. Flint of the Westinghouse Machine Co. did not reach the meeting in time to be read:

INTERNAL COMBUSTION ENGINES.

The sudden modern development of this type of engine makes it seem a very youthful prime mover, but as a matter of fact it has a history almost as long as the steam engine, dating from the latter part of the seventeenth century.

The first effort was with gunpowder as a fuel. This was unsuccessful.

A series of different experiments followed, but little success was obtained until Lenoir, about 1860 built and sold engines to run on illuminating gas. They operated without compression, and their economy was so much poorer than the users were led to expect, that they were quickly superseded by Otto and Langren's free piston engine a few years later.

But there is no occasion here to follow further the sequence of development. It is very interesting to note that many things which have since proven useful were hinted at

very early in the development of gas engines. For instance: jump spark ignition appeared in the Lenoir engines. Two-cycle engines which even now are of only limited success, were described at an even earlier date and in fact much preceded the four-cycle principle which was fully explained by Beau de Rochas in 1862, and successfully put in practice by Otto in 1867.

The development of gas engines has been much influenced by the fuel they had to run on. First it was expensive illuminating gas, and the only demand was for very small sizes where the amount of fuel was small and the convenience and saving of labor were the great inducements. Probably next in order came the oils and gasolines, the latter being easily utilized and very readily transportable. These fuels, however, with the exception of crude oil, are too expensive to compete ordinarily with coal when large powers are concerned.

Natural gas in this country, Producer gas in England and France, and Blast Furnace gas in Germany have led to very marked development in the building of large gas engines.

The experience gained with one fuel is an aid in the problems with others, and today large engines are being built and operated in this country on all these varieties of fuel. It is also interesting to note how each type of engine and fuel has qualities which especially adapt it to certain particular local conditions, so that engineers find themselves justified in using all the different varieties.

An illuminating gas company often finds it can with advantage burn some of its own gas in gas engines and sell electricity. A summer-resort hotel will prefer a gasoline engine and direct connected dynamo for its short seasons' lighting, even in spite of the high price of the fuel. For a similar reason, a water power plant may supply itself with gasoline engines for emergency use. A street railway company will put in producers and engines to get the full advantage of cheap fuel for its long hours of service. A steel mill will utilize much of its blast furnace gas directly in engines

instead of wastefully burning it for power purposes under boilers. A coke manufacturing plant finds it can get power from the gas generated in its by-product ovens. An oil refinery finds a source of power in the first vapors from its stills which, while resembling gasoline, are too light to condense for commercial sale. A mining plant in some inaccessible locality finds that transportation charges on fuel make the best the cheapest, and lead to putting in coal, charcoal or wood producers to make cheap gas for gas engines.

The next fuel probably will be denaturized alcohol. Its commercial advent, however, will be much influenced by the rate at which its price can be reduced and that of gasoline increased.

[Before the Structural Section, March 5, 1907. E. W. PITTMAN, Chairman.]

Some Commercial Features of Structural Engineering.

BY EMIL GERBER,*
Member.

What I shall have to present are some thoughts, neither startling nor new, that have come to me during an experience of a good many years, about equally divided between railroading, consulting work and manufacturing; and I may, with some degree of fairness, ask that you consider it not a wholly one-sided view.

The time-honored definition of engineering is "the art of directing the great sources of power in Nature for the use and convenience of man." In this age of commercialism in the United States, where the dollar is the chief aim of most men, a new definition has been promulgated by an engineer of ability and prominence, viz., "Engineering is the art of making a dollar earn the most interest."

The old definition is perhaps the more comprehensive and elegant, but the latter is a forceful expression of the times which demands recognition, and a combination of the two may not be amiss, viz., "Engineering is the art of directing the great sources of power in Nature for the use and convenience of man in the most economical manner consistent with the object in view."

The design of monumental structures and ornate buildings seldom falls to the engineer. But even in such structures the engineer is called upon, and rightly so, to make the plans for the prosaic but necessary backbone and ribs on which the more beautiful features depend for support and stability.

The more general field of engineering, however, lies in the homely but useful structures on which our every-day

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business, conveniences, necessities and pleasures depend; and on which beauty, not to say ornamentation, is of a secondary character. I do not wish to say that the engineer should have no regard for beauty, but to emphasize that the primary object of most engineering structures is utility; and it is to this phase I shall more particularly confine my remarks; and to this phase also is most applicable that portion of the definition of engineering relating to economy and the art of making a dollar earn the most interest. When a new problem presents itself, therefore, the first question should be: "Is the object sought worth the expenditure in a broad sense?" If it is a purely economical proposition, the question narrows itself to "Will it pay in dollars and cents?"

Mere convenience is not a commercial reason for doing a thing unless by such convenience a dollar can be saved directly or indirectly. Many enterprises have failed to pay because the designer spent much money on convenient things which made no return. It is sometimes even good engineering to make things inconvenient to guard against objectionable or expensive practices.

The general worth of the proposition being established, the details of the design must be worked out, and in this detail the engineer finds his opportunity to show his ability. Engineering is a mass of detail and he who grasps detail in the most efficient way in his young days will be the man who can master the larger problems most ably in more mature years.

A careful study of precedents is essential in these days. "There is nothing new under the sun" is becoming more nearly true every day. I do not wish to detract from originality, but indifferent originality is more expensive and less creditable than good imitation, and the success of the engineer is directly proportional to the success of his work and to the lowness of its cost. Neither should precedents be followed blindly, but the simplest and most direct means to the end should be sought and used. And simple things can often be learned from very humble sources.

I once had occasion to make some borings in ground sub-

merged under fifty feet of water and to bring up samples of the material encountered. Quick and approximate results were desired. It was easy to sink a pipe by means of a jet of water into the ground, but it was another matter to get the samples. The pipe had a reducer and nipple at the end and a valve, which could be removed easily while sinking and put in place when sampling was desired. One of the men suggested the use of a large marble which could be dropped down the pipe when the proper depth had been reached and removed with the sample when the pipe was withdrawn. The entire stock of suitable marbles in the little town was bought that night for one cent each, and for a week a single marble did the work admirably.

The conditions to be met must be carefully weighed, and while we should provide for all reasonable contingencies, it is often better engineering to neglect trivial things which may be possible, but either not probable or not troublesome, and let time take care of them, than to spend a lot of money in guarding against them in advance.

I have in mind a bridge in which an approach span was founded at the bank end on a block of concrete placed on top of a newly made embankment fifty feet high. The bank of course settled, very rapidly at first and less so as time went on. In the fifteenth year of its existence this span settled one inch at the bank end against several feet the first year. The engineer in charge in this fifteenth year criticised his predecessors' design of the foundation, saying it should have been carried to rock, which was about 120 feet below the rail, so that this settlement of one inch might have been avoided. The cost of such a solid foundation would have reached $100,000, if not more, whereas the existing foundation plus maintenance for the fifteen years was only a small part of that sum. Furthermore, the yielding of the foundation with the settlement of the bank made the approach span a self-adjusting incline requiring infrequent attention, while the solid foundation would have had no such elasticity and would

have required daily attention to keep the track supported as the bank settled.

It is perfectly proper to design each floor of a high building for a maximum load, but it would be a waste of money to design the lower story columns for the sum of all these heavy loads.

Reasonable allowances should be made for future developments, but we are seldom justified in looking ahead more than twenty or thirty years, for changes come so rapidly that the uses for which a structure is erected today may demand entirely different accommodations in a generation. Few of our iron bridges have served for thirty years, and some notable early steel bridges have been renewed in a little over twenty years. These bridges as a rule did not wear or rust out, but the loading increased with such marvelous rapidity that they could not safely sustain the heavier loads to which they were liable to be subjected. Steel frame office buildings date back scarcely a quarter of a century, yet some of them are being taken down to make room for higher or more convenient structures. As for mill buildings, the duration is still more uncertain, though the life of either might have been indefinite under original conditions.

Many of our great, magnificent railroads could not have been built when they were, and the new country would have been undeveloped for many more years, had the designing engineer spent any money not absolutely necessary for immediate uses. As it was, capital required abundance of faith when it was invested, in building as cheaply as possible the pioneer railroads of the great West, which paid no dividends for years but are now yielding a rich harvest. And who will say that because a community has not enough money to build a bridge to carry 100 pounds to the square foot, it must continue to ford the stream rather than build a 60-pound bridge which it could pay for.

We can afford to pay 50% more for a structure that will last just thirty years than we can for two structures that will last just 15 years each. $1,000 saved on a structure is worth,

at five per cent. interest, $4,320 towards renewals in thirty years.

In work involving articles of well-established lines of manufacture, or the use of equally tried processes, it is always advantageous to consult freely with the manufacturer's or contractor's engineers. Such men have probably encountered the problem to be solved, in some form or other, many times to our one, and know its difficulties, weaknesses and anomalies, and have eliminated many fallacies that look good to the eye but are largely illusions. They know also what their machinery can do well and cheaply, and what it cannot do at all, and details which have been worked out by them may at times look peculiar, but be the essence of economy and utility. These men may have hobbies of their own and may sometimes figure a little close, but they are sure to have eliminated the bad for their own good, and a comparison of the experience of several such men along similar lines will enable one readily to winnow the grain from the chaff.

Some years ago the English army required a bridge in Egypt across the Nile at Atbara. The home engineers, accustomed to special designs for each case, even down to making special rolled sections whenever fancy suggested, did not promise the bridge at an early enough date and American competition was invited, on American plans and methods, using sections which were quickly obtainable; the only stipulations being the loads to be carried, quality and stresses of material, and time of delivery. The American contractor built six or seven 140-foot railroad spans within two months, while it would have taken the English nearly a year. The bridge was erected in relatively equally short time by methods familiar enough to the contractor but unusual to the English engineers.

When the detail plans and specifications are being made, the best work that the occasion requires should be called for, but care should be exercised to eliminate the unnecessary and notional both in material and workmanship.

At one time American manufacturers were able to sell

locomotives to England for use there for less money than the home factories could. On examination it developed that it was not altogether because the American could produce metal and workmanship cheaper, but also because he omitted much needless work such as finishing surfaces which were just as serviceable in the rough and painted, thereby not only reducing first cost but also maintenance charges.

The cost of steel bridges to carry the same load over the same length of span varies widely according to the ideas of different designers, while the service and life of the structure is the same. Even when such spans weigh the same there is often a great difference in cost due to the relative degree of refinement on workmanship and material required, without adequate return for the higher cost.

The elimination of non-essentials is not only a saving of money in first cost, but it usually saves time in completion of work and it is needless to elaborate on the saying that "time is money."

The requirements for a railroad bridge are of a higher order than those for an ordinary highway bridge, and office buildings and mill buildings are each in a class by themselves and differ from bridges, and it is not good business to attempt to make all classes of work to one specification.

The specifications for structural steel presented today are pretty much alike and conform to what the mills can produce readily and regularly, but occasionally some one asks for some special requirement for ordinary uses, and while ultimately he may get what he asks for at no higher price, he usually has to wait much longer than for standard material. If steel is rolled and does not meet the special requirements, but is of standard quality, there are plenty of people who will take it at once and the replacement consumes weeks of valuable time. Meantime the interest charges on the money already invested run up.

In the design of the details of structures there is as yet no such uniformity as in material. The general plan or layout must of course fit the problem, but the details could be

much improved in the line of uniformity and in making as much duplication of parts as possible. Bridges slightly skewed cost more than square ones of a length equal to the gross length of skew spans, and trapezoidal buildings can generally be so divided that most of the connections are at right angles and that there are many pieces alike. Pieces that are alike should be marked alike, so that the commonest laborer can get with the least labor the piece that is required next. Office convenience in more readily checking pieces with different marks should not overrule the greater simplicity in all subsequent operations of common marking. The use of numerous sections in one structure is a frequent objection. The assumptions for calculations determining sizes are not so exact that we cannot deviate a little when it comes to a question of which of two similar sections to use, as for instance a heavy twelve-inch beam or a light fifteen. The more numerous the sections the longer it takes to get the material, for the mills roll each section only at considerable intervals and carry very little stock material. Odd sections should be specially avoided, as the interval between rollings is greater, and to know what is odd one must keep in close touch with mill practice.

The above is particularly applicable to minor fittings such as brackets and shelf angles, stiffeners and the like, the size of which depends less on stress requirements than on other practical considerations.

The calculations of rivets and pins are based on eminently safe theory, but it can hardly be called correct theory except so far as it is safe. When, therefore, connections of six or more rivets differ from each other theoretically by one rivet, or say 15%, we need not hesitate to make them alike. Floor beams have been known in railroad service to have flange rivets spaced 15 inches centers throughout their whole length and not fail. These floorbeams were improved by adding twice the original number of rivets, thus making 5-inch spaces, which was theoretically not enough, but the engineer argued correctly that if 15-inch spacing did the work 5-inch spacing surely would. There have been other floorbeams, I beams with

cover plates, doing good service with no rivets connecting cover plates and beams between stringer bearings, which, of course, is theoretically correct.

Similar reasoning can be applied to diameters of pins. In two important bridges the pins, figured by standard rules for bending, were subjected to fibre stresses as high as 250,000 pounds per square inch and yet were perfectly straight and sound.

I do not advocate changing pin and rivet theories, but merely wish to point out that some latitude is permissible.

Duplication of parts saves both time and money directly, and it pays well to have the draftsman study these matters carefully and thereby save the time of many men in shop and field.

Close fits and fine finishes, where not required for direct service or appearance in conspicuous places, are expensive and to be avoided. There is nothing more annoying to the erector than tight fits in field joints, requiring heavy hammering to get them together.

The making of specifications by the assistance of scissors is not uncommon and has some commendable features, but it should be done intelligently and a waste basket should be at hand as well as a glue pot. Results should be aimed at rather than processes, unless it is important to eliminate known bad practices. It is better to say in such cases what shall not be done rather than what shall be, as the contractor may have ideas of methods that are superior.

A prominent engineer once gave the two objects of specifications to be, to describe the results desired, and to keep the contractor from wasting time on trying to make cheap but doubtful material and methods, fill the requirements. Specifications should cover every point of importance clearly, but they should be as concise as possible. It would hardly seem necessary to say that cement shall be delivered at the site in manila paper bags containing about 80 pounds each and tied with hemp strings, when such a proceeding is common practice and wholly immaterial.

When the contract for work has been let, the end is not yet. The work must be made to plans and specifications and requires the eternal vigilance of the inspector. It has been said that no contractor can be trusted to do an honest piece of work. As I am in the service of a contracting corporation, it is of no avail for me to argue the point, except, that while practicing as an engineer I met many honorable contractors and it is my experience that confidence begets confidence, while suspicion creates antagonism and trouble.

It may be pertinent to point out a few features of the relations between the engineer and contractor. The contract specifies what each party is to do, and though the engineer is usually made the arbitrator of all disputes, and the contract gives him many arbitrary rights, this does not warrant him in exacting anything not distinctly agreed upon or reasonably implied, or in making changes without corresponding consideration to the contractor in money or time.

To the credit of most engineers it must be said that they are fair-minded, and if they will put themselves in the contractor's place and be fair, they are pretty sure to get a square deal.

To come back to the inspector, who deserves much consideration for the trying position he is in. He should be a man of experience, though frequently he has just graduated from college and knows about what all of us did at that stage of our career. An experienced inspector should be given plenty of discretion as to how he enforces his specifications. A wilful violation of course cannot be tolerated, but mistakes are made under the utmost vigilance and there will be accidental defects in material, and some remedy must be applied to get over the difficulty. If the inspector is really interested in getting his work done right and promptly, he will assist the contractor in devising the least expensive way out of the difficulty and still secure for his employer substantially what he pays for. A good inspector is a help to a contractor as well as to his employer and the men will point out errors to him so they may remedy them as he wishes, rather than conceal

them. But if the inspector is allowed no discretion and must live up to the letter of his specifications no matter how trivial the departure, there is sure to be trou, le, extra expense, and delay. The owner is entitled to his pound of flesh, but he should not shed unnecessary blood in getting it. The inspector's decisions should be prompt, many references to headquarters delays the work to the detriment of both contractor and owner, and such references gradually undermine the standing of the inspector. As the right is reserved that the inspector may be present in any part of the works at any time, so it becomes his duty to be present at any operation he desires to see, be it early or late, that the work may not be delayed on account of his absence.

Much stress is put on tight rivets, so much that some inspectors go about with a piece of metal in one hand and a hammer in the other to detect the slightest possible jar, hammering the rivet till it is loose if necessary, to prove a suspicion of looseness. It can be shown that few rivets of any length ever completely fill a hole, and such rivets can be hammered loose by a little persistence. The very theory of proportioning rivets assumes that they are loose, for they are figured for bearing and shear, the full extent of which cannot come on them till the pieces they hold together are so loose that they can slide on each other. The real work of rivets is to hold pieces together so tight that the friction between them is enough to make them act as a unit.

Loose rivets are not advocated, but when a rivet is so tight that looseness cannot be detected by sound or the bare finger with one or two taps, it is tight enough for all practical purposes wherever it may be located.

A source of expense and delay which is seldom considered is the changing of plans in minor details while the work is in progress. Changes, no matter how small, are always expensive in money and time, and they lead to those extremely objectionable bills of extras which the contractor usually makes too large for the owner but not large enough for himself. All changes, even if trivial, should be specified

in writing; in this way many of them will be found unnecessary. Large changes, of course, from their magnitude, force attention on themselves and are properly considered.

The entire cost of any structure is not always what the owner pays for it, but what has been spent on it altogether, for material, labor and interest charges on capital invested, which brings no revenue during construction. The latter is seldom figured. The owner should ordinarily pay all these charges, together with a profit to the contractors, but sometimes the contractor unwillingly contributes a share of the cost and gets no profit. So far as this loss is his own fault, he bears it as bravely as he can, but if it was inherent in the character of the work or due to unusual exactions during its execution, he will tell his story in very concise language the next time he bids on similar work for the same engineer by the figures of his tender. His estimate is based on a number of elements of which cost of material and average cost of labor for similar work are reasonably certain elements, while general financial, labor, shop and climatic conditions, and the personal equation of the engineer in charge are variables which differ for each case but must be considered.

In the long run everyone pays a fair price for what he gets, and if an engineer, in asking for proposals on work similar to work previously executed by him, receives a high bid from his last contractor, it is well for the engineer to investigate the reason, lest he is himself at fault in not having fully recognized the commercial conditions of his project. It is no credit to an engineer to boast that no contractor under him has ever made money. To such a person the cost will be a continually increasing one, and the owner, especially if he builds frequently, soon learns what current prices are and expects to get them, and if he does not he seeks and soon finds the reason.

If newspaper reports are correct, the proposed Panama Canal contract required the investment of considerable capital by contractors, which the government could itself furnish much cheaper and hence the contract was withdrawn rather than pay the price. Whether this is true or not in the Panama

Canal case is immaterial; it illustrates, however, that requirements may easily be made of contractors, against which the latter must protect themselves, which the purchaser has to pay for ultimately without getting much in return. Penalty clauses and guarantees are frequently of this boomerang variety. A case in point is the following:

The government let a piece of work and stipulated that ten per cent. of the purchase price should be retained for ten years as a guarantee for the durability of the work for that period. The contractor figured his cost plus a fair profit, then added the amount to be retained and this sum constituted his bid. He executed the work, made his profit out of current payments, and at the end of ten years collected his guarantee fund with interest as an extra profit.

The whole subject was admirably covered in a brief letter by the Chief Engineer of an important railroad who said: "We want as good bridges as any one and don't want to pay a cent more than they are worth and if there is anything in our requirements that adds to the cost without producing corresponding value, please point it out to us."

Others are making inquiries along the same line although the question is not so concisely put, and still others have mastered the problem and are getting good work, in quick time at a minimum cost.

What has been said may be criticized as a recommendation to accept mediocrity in engineering structures and looseness in business methods. It is not so intended, but rather to point out some of the things that have to be paid for in the long run, which are frequently not worth what they cost. The fundamental principle of all business is common sense, and the engineer who has plenty of this and is alive to the commercial side of his problem, as well as the technical side, will know where to draw the line between what is worth paying for and what is not, and will be able *to direct the great sources of power in Nature for the use and convenience of man in the most economical manner consistent with the object in view.*

DISCUSSION.

The Chairman: The paper is now open for discussion.

Chester B. Albree: Mr. President—I just want to say that in listening to this paper I have heard a great many things put in a very clear and concise manner, that come up in the experience of everybody engaged in engineering work, whether it be as designer, manufacturer, inspector or purchaser, and Mr. Gerber's paper has practically dealt with the point of view of each one of them. The contractor has rights, the engineer has rights, the purchaser has rights, and they all have to be taken into consideration. In any manufacturing concern it generally happens that they are not only contractors but very often themselves purchasers; they are buying buildings, they are buying machinery, this, that, or the other, on which they have to make specifications to be followed and plans to be carried out. In other words they have a chance to see the fairness necessary between contractor and engineer. I think Mr. Gerber has brought out these points wonderfully well. His illustrations have been particularly apt, and there are a great many practical points there about designing that it seems to me every engineer could read with a great deal of profit. I have been very much pleased with the paper and think it would be the best thing for the community at large if that paper could be published in all the technical journals in the United States.

E. K. Morse: I fully concur in what Mr. Albree says and I am satisfied before we get through with the paper, it will be published and circulated in a good many different countries, because our little journal is reaching many points it never did before. The reference made to the relations between the Engineer and the Contractor seemed especially happy. The natural tendency of the Engineer is to favor the Company and forget that he should always consider himself an arbitrator and decide accordingly. The Engineer often has it in his power to favor the Contractor without in the least slighting the work or in the least departing from the letter of the specifi-

cations nor in any shape or form affect the class of work done. I always make a studied effort to save the Contractor money and render any assistance possible, and have yet to meet the Contractor who doesn't thoroughly appreciate such efforts. I have never completed any work designed by other Engineers or designed or built any work of my own without sooner or later the condition of "Extras" developing, and it is then that it pays, if for only policy's sake, to be on good terms with the Contractor; and why not? After all, the Contractor gets the hard knocks and faces all risks. The Engineer who hasn't the courage to live up to his convictions is a coward and dishonest, and isn't worthy to be an assistant, much less direct important construction. The Engineer doesn't have to betray his trust or violate a word of the specifications and agreement to gain the respect of his employer and the contractor. All that he has to do is to be firm, honest and fair.

I regret to say it, but I firmly believe—yes, I know, of many cases where everything would have gone smoothly, the work would have been done on time, been entirely satisfactory, and the Contractor saved much cold cash, if the Engineer had only had a little back-bone. I believe that in a majority of the cases we hear about, the trouble is chargeable direct to the Engineer's narrow views and total lack of tact and good sense.

J. K. Lyons: I cannot add anything, except to emphasize the desirability of greater uniformity, along which lines there is ample opportunity for improvement. In fact this feature has not received the attention which its importance warrants. Man is prone to copy, or follow precedent, rather than try to simplify and improve construction, or use a duplicate of a previous structure. As an instance examine the clearance diagrams for the various railroad specifications; they are supposed to interchange cars, but the clearances are very different on the various roads. Is there any valid excuse for this difference? The fewer shapes used, as has been mentioned, the quicker will be the delivery. I recall a 60-foot through plate girder span that had fifteen different sizes of angles in it, and the saving of material was practically nothing as against using

six, or at most seven, different sizes. For a 150-foot through span I do not think it necessary to use over five or six different angles. This feature is not being observed so far as the business of designing is concerned, but it will come in time, and it will be much better for the manufacturers and purchasers; it will give good structures which will also be simple.

H. S. Prichard, Non-Member: Mr. Gerber has covered the field so well that there is not much which can be added to advantage. There is one important point, however, which he has not discussed. The strength of a structure depends quite as much on the details as on the main section of its members, but the details are not usually designed until after the price is agreed on. For this reason it is generally best to make the contract price by the pound instead of a lump sum. If the price is by the pound, there is no temptation for the contractor to skin the details, and the purchaser with entire fairness can have them as heavy as he pleases.

It was the experience of the New Jersey Steel & Iron Company, and doubtless has been the experience of all important manufacturers of iron and steel structures, that the personality of the purchaser's engineer has a very considerable influence on the cost per pound, and correspondingly on the price per pound, of such structures. The difference is not simply a matter of superiority in the essential qualities of the structures, but depends largely on the breadth of the engineer's knowledge, the attention which he gives to his work, his judgment, fairness and tact. The late William A. Pratt, for many years bridge engineer of the Pennsylvania Railroad Company, was a notable example of an engineer who by his reasonableness, fairness and strictness in all essentials, secured excellent structures for his road at very low prices.

To reliable contractors employing able engineers it is well to allow considerable latitude in the design, as these experts, by reason of their opportunities and practice, obtain special knowledge and experience which gives them many advantages in their specialty over other engineers, but it is not wise to accept unquestioningly anything which a contractor offers.

Some years since in inspecting stringers built by a large bridge company, it was noticed that the angles made by the end connections were not true, the error in many cases being as much as ⅜ inch in 26 inches. It was further noticed that there were many errors in length. The general practice has improved since then, but there are yet marked differences in the practice of different manufacturers of steel structures, and it is best, not only from the standpoint of the purchaser, but in fairness to the concerns which make a practice of doing good work, to insist on a proper standard.

In conclusion, the engineer who represents the purchaser should post himself on what is really essential and insist on it; he should encourage improvements in practice when it is practicable to obtain them, if they are worth what they cost; but he should avoid crotchets and should make wise use of the knowledge and experience of the contractor.

L. J. Affelder: One of the objections to the pound price contract is that a great many purchasers cannot discriminate between different classes of work, and once having been given a price per pound they will insist upon buying all their requirements for some time at that price, whether it is worth more or less. Of course that does not apply where a contractor is dealing with an engineer, but it often applies where one is dealing with a representative of the purchaser who is not an engineer. I think from the contracting standpoint the per pound or lump sum contract must be considered on its merits in each case, and no definite rule can be followed.

F. T. Cadmus, Non-Member: Mr. Gerber's remarks carry me back several years to the time when I was one of the inspectors such as he referred to. It was a very few months after I was initiated into the inspection business until I found out that I could accomplish with almost any manufacturing concern that I had occasion to deal with generally satisfactory results, without any trouble as long as the men in the shops were dealt with properly. Now that I am on the other side of the fence I always make it a point to deal with inspectors that

have occasion to deal with us as I liked to be dealt with when I was doing a similar class of work myself.

It is a fact, however, that a great many people do not stop to think of the necessities which the competition of to-day forces on manufacturers; the necessity for going into every detail of the work from an economical standpoint. These conditions have practically forced piece work, and very often in a discussion such as this the question comes up, "Does piece work pay and is it economical?" My personal opinion is, that were it not for piece work, or its equivalent as generally established in the large manufacturing plants of to-day, competition, which is so keen, would probably cause those who did not rely on such a system being relegated to the past in a very short time.

In the inspection of structural work it is a very difficult matter to cover up anything from the men in the shop, and our efforts are exerted towards training the men to uncover anything that is not strictly as it should be. All classes of mechanics, and particularly piece workers, are liable to blunder, and it is perfectly natural that they should try to cover up their mistakes and save themselves a calling down from the foreman for making such blunders. But when a management is inclined to be a little liberal and reasonable along these lines it undoubtedly encourages the men to be open and free, so that if a blunder is made they frankly report it to their superior. It is our aim to train our workmen to be free with the inspectors and bureau representatives, and while it is difficult with something like 2,200 men to have every one do his good part along these lines, yet I believe that inspectors in general find the conditions better to-day than ever before. I am quite confident that the men in all structural shops are training towards a better class of work. It is our aim to get in close touch with every inspector that comes to our shops, and endeavor to create a feeling of good will; letting him understand that it is not our desire to attempt to cover up the many little defects and errors that are bound to creep in as the work is fabricated in the various departments. We try to encourage

inspectors to keep us in personal touch with anything that is not right or that indicates anything underhanded on the part of our workmen. I feel quite confident that in itself this has brought better results and a generally better feeling between our employees and the outside shop inspectors; and from the comments of the bureau representatives the conditions in general are encouraging and indicate closer relations with the foremen and workmen in the shops, and there is no good reason why such conditions should not continue and at the same time improve year by year.

Morris Knowles: Referring to the question of originality versus standards or precedents, and more particularly speaking of practical designs, this is something to which we can readily give much careful thought. It is true, even along some lines where standards are not well established; where, perhaps, there is good opportunity to think that each new job calls for new treatment and we frequently find, particularly among younger men who are well trained in theory, a belief that the best effort means to produce something that no one else has done. This is one of the factors to be watched and guarded, in order that work may not be made too expensive because of these particular features.

On the other hand, this seeking after and following standards entirely may lead into some dangers, at least it does not make for advancement, because if we do not do anything different than has been done for years, we certainly cannot grow. The ambitious seeking after tonnage and after great output, does stifle and keep down original thought. It is natural that this should be so. It is not always to be laid at the doors of the men who have intimate and direct charge of this work, but to those who control the finances and desire an output that will be bigger than that of the year before, and that which will bring correspondingly greater return.

I have a particular incident in mind, where for many years different concerns have followed their own minds in regard to specifications for cast iron pipe; some have had one practice and some another, and there was not a uniformity in the de-

tails of parts. Recognizing this, an organization of water works people took up this matter and prepared a schedule of standards and later it was approved by other organizations. Realizing the advantages, the manufacturers prepared a standard which differed slightly from that of the water works people. The result is, as I learned only yesterday, that certain foundries, on account of business being so good, will not consider bidding on miscellaneous specifications, but will only bid upon these standard specifications as prepared by themselves. This indicates the tendency and practice of the present day.

Another incident comes to mind: I remember some years ago that in building a large riveted steel pipe line the steel plates were rolled in Western Pennsylvania and shipped in covered gondola cars to the shop in the east, and there the pipe was made. Much importance was laid on the fact that the plate was kept clean and there was no opportunity for dampness to gather on them and rust them in transportation. Recently however, we learn that it is difficult indeed to secure protection of any character; the demand for tonnage is so great, it is hard also to secure cars, and especially is this so if one desires a peculiar type of car with removable cover. Thus the entire matter of protection has been lost sight of and we find that one must take this material in whatever way it can be secured. In other words, the great output is the factor.

In connection with the remarks of the writer covering the question of periods for which work should be designed: It may be of interest to mention something of our own experience in water works design. It is a somewhat frequent criticism that water works for municipalities are not designed forever, and that within our own memory works become useless and have to be enlarged or changed. I think we lose sight of the fact in this criticism that conditions change as well; that which people consider to-day is not suitable for the demands of another generation. Therefore it is not wise to spend too much money, in order that works may never be changed. We learned in the seventies, when Boston first built an additional supply, that on account of going so far into

the country it would be all that would be needed for all time, and this would be the end of the water question. Later in the nineties the agitation for more and purer water was carried on and works were built, which are just now being completed, of a still greater capacity and from new sources. Even this we now realize is not all, and there are places to which they may go still further in the future to obtain additional supply.

The same is true of New York City, first going only a short distance and then still further to the Croton watershed, and now we hear of their going to the Catskills for still greater supply. It is not true that these changes are due to false steps, nor are they errors; they are simply the result of solving the problem each time with the best information at hand, and as conditions have changed new solutions present themselves.

But to get nearer home: It has been suggested that possibly the Allegheny river water will not be good enough to supply the City of Pittsburgh forever. This may be true; I do not know and cannot tell; but at any rate such a problem must be worked out gradually through the generations to come. It is very likely that the worst fear that the river will become more and more polluted will not be true if the energetic force of our excellent State Board of Health will bring about the results contemplated in purifying the stream and in rendering less potent the contamination which has customarily entered it.

Another thought which the writer mentioned was that of the beautiful: It is true, although the Engineer may not have artistic ability, that he should give attention to those things which promote a pleasant view to the eye, as distinguished from the strictly utilitarian ideas. It is right that some money should be so expended, provided it is wisely done. Too often it is true that the design for strictly the question of stability and usefulness is subordinated for the strictly artistic. The exterior is frequently designed by an Architect with requirements given to the Engineer to fill in as best he can. The true way appears that a building should be laid out for its purpose and designed strictly from the standpoint of utility and

question of stability, and then the artists and architects be asked to draw the exterior in such a way which will make pleasant harmony to the eye. Frequently it may be found that some slight changes can be made in the previous work to better accommodate this desire.

In regard to the attitude of the Engineer and the Contractor: The previous remarks have largely come from those engaged in supplying material, and many of their remarks are only too true; the closer relationship of the Engineer and Contractor always makes for best effort and result. There is, however, another thing which should be considered and of which we must not lose sight. The Engineer for a corporation, while of course he is responsible to a large body of stockholders, is immediately responsible to a small body of men, usually a Board of Directors, or it may be an Executive Committee. The people of general interests may learn indefinitely and vaguely, but not intimately, of his work and his characteristics. On the other hand, the municipal or government Engineer, whether for a City, State or larger body, is the football for everybody's criticism and particularly those of the newspapers. Everyone feels free to criticise his most trifling act. He therefore may think many times of the effect which his acts will have and he therefore may deal with considerably greater conservatism and strictness than one who does not have so captious a clientele.

Mr. Gerber: I do not know that I have anything further to say, except to refer to Mr. Knowles' remarks about the municipal engineer. His is a position where he is practically tied absolutely to the letter of his specifications, even though a liberal construction of them might produce better results. I have a case in mind where that was very strongly illustrated. The engineer was a man of good common sense and ability, but when something differing from the requirements by less than one-half of one per cent. was presented to him, he was compelled to decline it, because if he had not and the public got hold of it, they would make political capital out of it and there would be no end to the criticism of graft or favoritism. It is

very unfortunate that the public holds its servants down so closely and minutely to things of that kind, that they cannot exercise discretion, for such vigorous exactings increase the cost of public work. It is not so much of a hardship on the contractor as it is on our public servants themselves, and ultimately on the taxpayer. The very fact that public officials are so rigidly held down makes their position very unpleasant for them at times, and hence undesirable to able men, if anything else can be found. Very frequently the public goes into these discussions with very little knowledge of the real facts. Such discussions should be avoided, but, unfortunately, the public reserves the right to criticise anything at any time, without much investigation.

CHARLES DAVIS
1837-1907
TWELFTH PRESIDENT OF THE SOCIETY
1894
(SEE MEMOIR)

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S. M. Kintner, President,
In the Chair.

History of the Development of the Manufacture of Iron and Steel Sheets.

BY W. C. CRONEMEYER,*
Non-Member.

Mr. President and Gentlemen:

When I received from the chairman of your programme committee the invitation to appear before your society and read a paper on "Rolling of Sheet Metals," I felt much hesitancy as to whether I should accept or decline such an invitation, for on the one hand I consider it a rare honor that members of this society, for which I have always had great respect, deemed me worthy to appear before them as a lecturer; on the other hand I had doubts in regard to my own ability, at the present time; but then recollections came back to me of the time when I and my business colleagues were struggling hard to establish a tinplate industry in this country and we could not find any mechanical engineers who possessed a special knowledge of that branch of industry; when in fact none of the engineers in Pittsburgh deemed it worth while to lose any of their valuable time in making a study of the subject. In consequence we were compelled to

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forge ahead with our own crude knowledge and our practical, but sometimes very costly, experience—for you know the tinplate industry was reared as one of Uncle Sam's step-children, and in its infancy was always in danger of dying from neglect; therefore it could not offer many inducements for lucrative employment; almost all other branches of the metal industries but Tin Plate, were carefully fostered by high government protection and therefore presented a better field for cultivation, but when finally in 1890 tinplate making was admitted to the sisterhood of protected industries the sentiment towards the same changed at once and our little plant at Demmler, which at that time, by gradual improvements on our first crude ways, represented a monument of corrected mistakes, became a regular Mecca of the pilgrims who were now anxious to participate in the blessings offered by Government protection. Our mill which, as said, was rather crude and small in the beginning had been added to and improved, a little here and a little there, and thus did not, of course, represent a model of modern engineering; but it showed what was required to be done and what we had intended to do; the mistakes we had made and how we had endeavored to correct them; and thus it afforded the engineering talents a good basis for study. We were glad that they made use of the opportunity we offered them because the development and success of the American Tin Plate Industry and our own industrial existence depended largely upon their endeavors for further development. The results of American engineering ingenuity and endeavor in developing the American Sheet Iron and Tin Plate Industries have demonstrated themselves during the last sixteen years, so obviously that I will not dwell on that at this point but may bring some of it to view in my talk later on.

The same sentiment that impelled us to open our mill to students and investigators sixteen years ago prevails with me now. I have not had in my younger days, like most of you, the benefits of a technical and scientific education, and even now I have been for several years out of practical con-

nection with this industry, and therefore my knowledge of the subject of which I am to speak may in some respects be incomplete and my talk will be a narration of developments rather than a scientific treatise; but just as twelve to sixteen years ago the promoters and engineers of the then contemplated tinplate and fine sheet iron works took many points and suggestions from the old and crude mother tinplate mill at Demmler, so I hope that at this time you may be able to take some suggestions and form some new ideas by listening to my old-fashioned talk. And having made this explanation I feel confident that you will be generous in your criticism.

While the process of producing forged iron has been known since the beginning of our earliest history, the process of reducing forged iron by rolling was not invented until somewhat less than two hundred years ago; in olden times plates and sheets of iron were produced by hand hammer on the blacksmith anvil and naturally of comparatively small dimensions only. Pieces of wrought iron were heated in open fires and hammered flat and as thin as possible, then several pieces were piled on top of one another, reheated to a red heat and again hammered until the several layers had been brought down to the required thickness, and the thickness of the several plates were naturally rather uneven. Later the crocodile or helve hammer, driven by water power, came to ease the hard manual but skilled labor of the smith. The art of rolling sheets by means of cast iron cylinders was first introduced in England early in the eighteenth century. Some historians credit the invention to Major John Hanbury, while others report that John Payne constructed the first sheet rolling mill in 1728; both the gentlemen named seem to have been prominent in the industrial life of their period. The perfecting of the steam engine, which soon followed this invention, and the use of steam power, which was then employed in driving the rolls, assisted materially in the further development of the art: the sheets produced by the new method were found to be much superior to the old hammered sheets in that they were more pliable, of more uniform thickness and could be

produced in much larger dimensions; and most important of all, at much reduced cost.

By this invention England had been enabled to turn the tables on Germany, where previously the manufacture of thin sheets, especially tinned plates, had reached a higher stage of development than in the former country. Strange to note, however, is the fact that mills with grooved rolls for rolling bars, etc., do not seem to have been used in England until forty or fifty years later.

Contemporaneously with Hanbury and Payne in England, Christopher Polhem, a Swede, designed mills for the rolling of sheets and bars, also for the rolling of steel for knife and sword blades, and from his memoirs which are quoted in Swank's History of the Manufacture of Iron in all Ages, it appears that Christopher Polhem had at that early date already conceived the principle of the three high mill, which Mr. Bernhard Lauth invented, and which was introduced into practice through his son, Bernhard C. Lauth, in this county in 1863; with the difference that Polhem used *two* smaller diameter rolls between the larger top and bottom rolls instead of only one.

Quoting further from Swank's History: "Gabriel Polhem, a son of Christopher Polhem, in the transactions of the Royal Swedish Academy of Science for 1740, gives a description of a rolling mill, the invention of his father which he, Gabriel Polhem, put up at the mint in Cassel, Germany. He says that the officers of the mint did not believe that a rolling mill could be of any use for the mint but he was, nevertheless, in 1733 ordered by King Frederick to put it up and it proved most useful for getting more uniform thickness and weight of the coins. From this and other expressions in the description it is quite clear that the said rolling mill was the first one put up at any mint, but not long afterwards a rolling mill was also put up at the Swedish mint. Aside from the Polhelm mills there does not appear to be any evidence that rolling mills were put to use on the continent of Europe until very late in the eighteenth century."

Until the beginning of the nineteenth century, charcoal was the fuel used exclusively in the production of raw iron for sheet purposes, after that the use of mineral fuel, coal and coke came into vogue to some extent simultaneously with the puddling furnaces.

In the United States the rolling of iron sheets was first started early in the nineteenth century. It appears that the first, or at least one of the first, American Sheet Rolling Mills was built in Pittsburg in 1818. In Swank's History, to which I have already referred, we find a quotation from the Pittsburg Almanac of 1819, as follows: "A very extensive establishment under the superintendence of Joshua Malen, formerly of Valley Forge and whose talents will be an important acquisition to this section of the Union, has been made by the Pittsburg Steam Engine Company. At their mill, which has two engines, each of 120 horse power, will be manufactured bar and rolled sheet iron."

The location or the identity of this plant I have not been able to ascertain nor whether it ever went into actual operation and produced rolled sheet iron in those early days. The first distinct records I have been able to find of sheet iron making in America are those of the works of Alan Wood near Wilmington, Delaware, where nail plates were rolled as early as 1812 and thin sheet iron about 1829. Marshall's sheet rolling mill near Newport, Delaware, was built in 1836 and several more sheet iron works were established in Delaware, Eastern Pennsylvania and New Jersey between 1840 and 1860. Alan Wood, the grandsire of the Wood family whose name has become famous in the Sheet Iron Industry, removed his works to Conshohocken, Pa., where the now extensive works are still in possession of and are operated by the grandsons and great-grandsons of the founder. W. Dewees Wood, one of the sons of Alan the first, was the founder of the Planished Sheet Iron Works in McKeesport, but to that subject I will refer again later on.

In Pittsburg the production of thin sheet iron began to flourish during the fifties and sixties of the last century, espe-

cially after the Civil War when a high protective duty was imposed upon such as well as other products, a large number of the owners of sundry iron works then added one or more trains of sheet rolls to their respective establishments and operated them in connection with their merchant mills. At that time Jones & Laughlin, Shoenberger & Co., A. M. Byers & Co., Zug & Co., and others were making common sheet iron along with their other products, prominent among those who confined themselves to sheet iron exclusively or made them their chief product were Moorhead, McClean & Co., and Everson & Preston. The oldest sheet iron mills West of Pittsburg are, I believe, the Falcon Works at Niles, O.

After 1875 the production of common sheet iron increased rapidly, a large number of new works were built in Western Pennsylvania and Ohio. Time forbids to enumerate them all.

As the light sheet iron industry in both the Eastern and Western Section grew, two distinct methods and two different kinds of product were developed.

In the East prevailed what was called the loose mill or the Philadelphia Style, while in the West the tight mill or Pittsburg Style was adopted as a rule. The difference in the two styles of rolling and the subsequent product consisted chiefly in the fact that the Eastern mills used one piece of thin flat bar for each single sheet and the Western mills would produce two to four sheets of gages lighter than No. 22 from one piece of thicker bar. In the Eastern style the bars having been cut into lengths which corresponded with the required width of the finished sheet, were first rolled single in a roughing mill to about No. 16 gage. Of the plates thus obtained from two to six, according to the required thickness of the finished sheets, were matched, that is they were placed on top of one another, a sprinkle of charcoal dust being thrown between the several layers. The pack thus obtained was then reheated and rerolled until it became too cold for further easy stretching, when the several sheets in the pack would be separated and the pack so re-arranged that the sheets which had been on the inside would come to the outside and vice

versa. A further sprinkle of charcoal dust was then applied either before or during the subsequent rerolling; the charcoal dust was used mainly for the purpose of preventing the sheets from sticking or welding together. By such means the latter could be subjected to a much higher degree of heat and would consequently stretch more quickly than if no dust had been used. The rolls were kept cool by squirting water on them. In this manner the sheets came out with a cover of black oxide and a surface of practically uniform color, and which offered considerable resistance to further oxidation: The still adhering black dust, however, was a rather disagreeable feature for the sheet iron worker. The finished sheets after being trimmed or sheared to correct sizes would be annealed in an open fire (generally after the day's task of rolling was completed), in the same furnace in which they had been previously heated during the rolling process.

I believe the principal feature of this system still prevails in the East, although many improvements have been made in the finishing processes. In the rolling of sheets not thinner than No. 21 gage, there was no material difference between the East and the West, but for rolling sheets No. 22 and lighter the Western mills with, as far as I know but the one exception of the W. D. Wood Company in McKeesport, adopted the doubling system. In this system two pieces of bar constitute a pair: the two pieces are brought out of the furnace simultaneously and pushed through the rolls successively, one right after the other until they are down to about No. 12 or 14 gage. The pair is then matched and put back in the furnace, reheated and rerolled, and the pack is then bent over in the middle and doubled, so that there are now four layers in the pack. The pack is heated again and rolled out to the required length. Sometimes as the required thickness and length of the sheets demand, three single sheets are matched so as to make a final pack with six layers. Sometimes when very thin sheets are to be produced, packs with four layers are doubled, heated and rolled again, so as to make a pack with eight layers, and in recent years as many as sixteen

sheets are rolled in a pack. In this process no dust or welding preventer is used between the sheets, and therefore the sheets must be rolled at a lower heat, and the raw material must be of a quality that will not weld too readily at that heat. The surface of the rolls, which expand in the middle as they get heated up, must be turned to a concave shape, that is, their diameter must be slightly smaller in the middle than on the ends. The doubling of the sheets, which was in the early days accomplished by beating down the bends in them with big wooden mallets, is now almost universally done by mechanical devices attached to the shears with which the rough edges and ends are cut from the sheets during the process of rolling, or by separate machines. After the packs have been trimmed or sheared to correct sizes the several sheets are separated or opened and as they generally adhere pretty tightly together it requires some little strength and skill to separate them. While the two outside or top and bottom sheets of the pack which have come in direct contact with the rolls have a smooth oxidized and uniformly colored surface, the oxide on the inside sheets is very thin and when the sheets are torn apart will adhere in spots or flowers, sometimes on one and sometimes on the other sheet, leaving a corresponding clear or deoxidized spot on its mate, and thus bring about a variegated surface. While such sheets are not as desirable as the Eastern style product for stove pipes and other similar purposes, where the surface is to remain in its natural state, they are more serviceable by far when the adhering oxide is to be removed, or they are to be coated with other metals, or substances, or are covered up otherwise. In the early days many of the Western manufacturers annealed their products in open furnaces, the same as was done in the East, but now all light sheets are annealed while packed in closed boxes—unless it be that during the last year or two the quick open fire annealing process has been found to be more serviceable for certain purposes of work.

The main principles of the two different styles or processes which I have tried to describe to you still prevail in the making

of the ordinarily finished or common grades of sheets; but on the basis of both of them considerable progress has been made in the production of more highly finished sheets.

During the last two decades several inventors and mill designers have tried to break away from the old time methods of rolling sheets, and quite a number of patents have been issued on improved sheet rolling mills, but of all of them only the most recent one has entered into actual practice. I refer to the "Bray Mill," which now bids fair to be the means of eventually revolutionizing the old methods.

The Bray Mill might be called semi-continuous. It consists of a large continuous bar heating furnace in which the bars are heated while they are carried by an automatic device from the charging end to and out of the discharging end of the furnace, where they drop on the fore plate of the mill and are carried successively through four or five pairs of rolls set at tandem. When the plates emerge from the last of these they are in the shape of singles (so called). By a mechanical device every alternate plate is arrested after it has emerged from the rolls until the next sheet is also out and lies on top of the first and thus form a pair. The pair then moves along again until it rests under a pair of rolls, arranged side by side horizontally; then a pusher strikes the pair of sheets from below, bends it in the middle and pushes it into the nip of the horizontal pair of rolls, from which later it emerges as a pack of fours which is taken over to the black plate finishing mill, where it is reheated and rerolled to a finish.

The first and tolerably successful attempt to bring out in America a highly finished sheet iron product, that could compete with the glossy and uniformly blue colored Belgian Sheets; and especially also with the Russian iron of which large quantities were imported every year, was made by the Alan Wood Company of Conshohocken, Pa., about 1865. The counts of Demidow who were making the Russia Sheet Iron with the help of their serfs in the depths of the Ural Mountains kept their process a profound secret and it was then generally believed that such fine material could be produced

only from the peculiar kind of magnetic ores which were found in that region. But the Woods' proceeded, nevertheless, on the basis of their own methods by thoroughly cleaning their charcoal iron sheets, removing the heavy oxide by means of acids, re-oxidizing and re-blueing the sheets, and polishing the same in highly ground chilled rolles. About the middle of the sixties W. D. Wood branched off from the parent concern and came to McKeesport, where he carried on experiments on an extensive scale in annealing, cleaning, oxidizing and polishing processes. In about 1872 he started to give the material a highly finished mottled surface by polishing the sheet under planishing hammers with large chilled face dies; and thereby gave it the appearance which was one of the chief peculiarities of the Russian Iron. From year to year the product has been further improved so that the sheets which are now being turned out at the works (which in 1900 came into possession of the American Sheet Steel Company) surpass the original Russian product in finish and uniformity of gauge, and have driven the latter out of the American market almost entirely.

In 1870 or 71 Rogers and Burchfield commenced at their works at Apollo and Leechburg, Pa., the manufacture of cold rolled and pickled and cold rolled sheets. Mr. William Rogers, who had come here from Great Britain, where he had learned the art of producing fine sheets in the Welsh tinplate works, succeeded from the start in turning out a superior product which took very readily with the trade and found large demand. His methods were in principle the same as were in vogue in the other Western mills, but by cautious heating, avoiding scaling or heavy oxidation and by keeping the hot mills and cold mills in good trim and the rolls well polished, he managed to turn out a product superior to the regular run of the common sheets which were turned out in those days, and which were to form the basis for further manipulations.

The raw material used was principally charcoal iron bar, made from hammered blooms and if puddled bars were used,

they were as a rule, refined by forming a pile of them, putting a charcoal bar on the bottom and the top of the pile, reheating that pile and rerolling it into the required sheet bar. To produce extra fine qualities for stamping purposes etc. the refining process was even further extended by piling best refined charcoal iron bar, reheating it, forming it into a billet under the steam hammer, again heating it and rolling the finished sheet bar.

If the sheets were intended for purposes that required simply good material with a smooth surface, they were cold rolled only in polished cold rolls after they had received their first box annealing and were then re-annealed to take out the brittleness produced by the cold rolls—but if the material was to be used for stamping purposes or was to be cut up into smaller pieces in dies, or if it was to be tinned, the scale or oxide was removed from the surface by pickling the sheets in sulphuric or muriatic acid before going into first annealing —then after annealing the manipulations were about the same as with the sheets that were cold rolled only.

The demand for cold rolled, and pickled and cold rolled, sheets has become very great in late years, but the manipulations in producing those finishes have remained practically the same to the present day, only that the pickling which was formerly performed by hand labor is now done with the aid of pickling machines.

In 1875 Mr. Rogers went to Russia and the Ural Mountains to study and learn the process by which the Russian Iron was made and when he came back he reported that he had found out the secret, and began the erection of furnaces and machinery for the purpose of starting the manufacture of such product, but soon after his return his firm got into financial difficulties and went into bankruptcy; while Mr. Rogers became afterwards again for a while part owner of the Apollo mills, and was otherwise engaged in the manufacture of sheet iron, he never carried out his intentions in regard to the manufacture of Russia Iron. But some of his successors in the Leechburg mill have in later years, suc-

ceeded in producing some creditable products in that line by the use of soft steel. The production of Pickled and Cold Rolled sheets was considerably increased in about 1874, when the U. S. Iron Tin Plate Works at Demmler, Pa., and the American Tin Plate Works at Wellsville, Ohio, were built for the purpose of manufacturing tin plates. The companies operating these works soon found that for want of the government protection which had been granted to nearly all other branches of the iron industry, they could not compete with the imported Tin Plate, and as the machinery needed and the manipulations to be performed in the production of black plates for tinning are about the same as those required for small sizes of Pickled and Cold Rolled sheets; or more correctly speaking as the so-called Black Plates are small sizes of Pickled and Cold Rolled sheets, they devoted their attention to this branch of the business; fortunately for them the manufacture of stamped and enameled iron ware had just been introduced into this country by the St. Louis Stamping Co. and the Lalance & Grosjean Mfg. Co., both had so far been importing their stamping plates but now became good customers of the U. S. Iron and Tin Plate Co., and of the other works which subsequently made arrangements to supply the growing demand. The Iron Clad Can Co. of New York started the manufacture of heavy Railroad Milk Cans and used quantities of P. & C. R. sheets for that purpose. Tinned iron spoons, japanned and decorated iron show cards, came in vogue and many New England manufacturers began to use P. & C. R. stamping iron as a substitute for Malleable castings. The American Tin Plate Co. gave up the business about 1878, the works were sold to W. Dewees Wood, who formed the Wellsville Plate and Sheet Iron Company and remodeled the works into a Sheet and Plate Mill, but arranged also for the manufacture of cold rollel sheet iron. The Apollo Works, formerly owned by Rogers and Burchfield, were purchased from the Assignee by Rogers, Laufman & Co. and the Leechburg works formerly owned by the same firm were purchased by Kirkpatrick,

Beale & Co., at both mills the work was resumed where Rogers & Burchfield left off. During the period from 1879 to 1887 there emanated from the Leechburg works the firm of Jennings, Beale & Co., the Cannonsburg Iron & Steel Co., and the firm of Wallace & Banfield, all composed partly of former partners or employes of Kirkpatrick, Beale & Co., and all entering into the manufacture of fine sheets. About 1886 Rogers & Laufman consolidated with the Volta Iron & Galvanizing Company, forming the Apollo Iron & Steel Company of which Mr. Geo. McMurtry was made President. Mr. P. H. Laufman severed his connections with this Company soon after the consolidation, built another works at Apollo and engaged in the same line of business. Under the leadership of Mr. McMurtry the original Apollo works grew very rapidly and later a branch works was established at Vandergrift, which, I believe, is at present the largest sheet iron works in the world.

During the decade from 1880 to 1890 the business in stamped and enameled ware grew so rapidly that the St. Louis Stamping Company and the Lalance & Grosjean Mfg. Co. extended their facilities by building their own sheet mills the first at St. Louis, Mo., and the second at Harrisburg, Pa. Thus it will be seen that by 1890 the fine sheet iron industry had grown to considerable importance.

THE INTRODUCTION OF SOFT STEEL.

While the industry was thus growing an entire new feature entered into its development, viz.: the use of soft steel. The first attempt to roll soft Bessemer Steel into sheets was made at the U. S. Iron and Tin Plate Works in 1876 (where I was Secretary and Business Manager). Our works were built for the purpose of making Tin-plates but as I have intimated already, we found that without the protection which was bestowed upon all kindred industries but was denied to Tinplates, we could not make the business pay, and were compelled to hunt other sources of making a living. At a visit to our neighbors the Edgar Thompson Steel

Works, which were built at the same time as ours, where Captain William Jones was Superintendent and Mr. H. Preusse, Chief Chemist, I saw a large pile of rail bloom ends for which the manufacturers had no special use. Previous to this we had filled some orders for Shovel and Scoop iron, which required tough stock with an acid cleaned or what we used to call, pickled finished surface; it struck me that if we could get the bloom ends reduced into sheet bar that they would make good raw material for our shovel stock. Suggesting this to Captain Jones he took to the idea with celerity and agreed at once to roll the ends into a shape of billets that would fit our bar rolls so that we could break them down into the proper size sheet bar. The experiment was a success from the first go. The thicknessse of the plates we rolled were from 14 to 17 gage, or singles.

The superintendent of our works was at that time, Mr. John Cole, a wide awake mill man, previously assistant to Mr. Wm. Rogers at Leechburg. When he found how well the steel worked into singles he tried to work the stock in doubles and fours, but it being rail carbon stock, found it too hard and stiff; so we concluded to have further consultation with Captain Jones and Mr. Preusse and from that our visits to Edgar Thompson Works and Jones and Preusse's visits to the U. S. Works were very frequent; although I must confess that every time I went into the Steel Works I became almost green with jealousy and envy when I saw how under high protection the steel rail business grew like a mushroom while our tinplate plant was just like a sickly little tropical flower thrown by the wayside in a Northern climate.

The result of our consultations was however that Mr. Preusse under direction of Captain Jones, made a special mixture for a charge of low carbon steel for our purpose, and this experiment again proved a success from the very first, in the bar mill as well as in the sheet mill; and in the pickling, annealing and tinning process. We found that the percentage of wasters or seconds in tinning were only about ten per cent. when with the use of charcoal iron we had never less,

but often more than twenty-five per cent. We were then living in the hope that this discovery might help us to continue the manufacture of tin plates, but at that time steel billets were costing $55.00 to $60.00 per ton against $28.00 for muckbar and $36.00 for charcoal blooms, and the iron-workers thinking that they must get some benefit from the innovation demanded fifteen per cent. advance in their wages for working such product, and thus the advantages gained were not sufficient to overcome the many disadvantages which obstructed the progress in Tin Plate making; and we had to give up the manufacture of the latter in spite of the new discovery. However, we continued to use the soft Bessemer in many of our other black products and other mills began to use it soon after. It appears that the use of soft steel in the making of sheets and tin plate was not introduced at the English mills till about 1879 or 1880. Inasmuch as the surface of sheet steel is much cleaner and denser than that of iron it can be blued or oxidized more readily, and this circumstance was utilized at the Leechburg works in bringing out the Craig Sheet Steel, an imitation of Wood's Planished Iron, at Cambridge, Ohio, they made the Morton Polished sheets, the U. S. Works produced the U. S. Polished, the name of which has since been changed to Wellsville Polished.

How the use of soft steel for sheet purposes has grown and how it has dispelled the use of iron almost entirely is a matter of recent history with which the most of you are no doubt familiar.

THE COATING OF SHEET IRON WITH OTHER METALS.

To protect sheets of iron and steel against quick corrosion they are plated or covered with a coat of such other higher grade metals as will suffer less under atmospheric influences. Of the two methods by which such coating or plating can be accomplished (viz.: the dipping process and electro-plating process) the former is now almost exclusively the one practiced in the iron and steel industry, and tin, lead, zinc and sometimes an alloy containing antimony, are

principally the metals used for such purpose. Copper coating by means of electro-plating and welding processes has been introduced at various times, but never as far as I know, with any great success.

Of zinc, tin, and terne (alloy of tin and lead) coated sheets, however, large quantities are produced and consumed.

Exact data regarding the beginning of the zinc coating or galvanizing industry I have not been able to obtain. In this country it began to flourish during or right after the civil war under the impetus of the Morrill tariff.

At that time and until the middle of the eighties the galvanizing was done largely by people who carried it on as a separate business in connection with the coating of other articles and who did work for the rolling mills or bought the sheets and traded in them themselves.

Amongst the first mill owners who did their own galvanizing were Moorhead, McClean & Co. Pittsburg, who made the once favorably known "C. H. B." brand (charcoal hammered bloom). After the formation of the Apollo Iron and Steel Co., to which I have referred already, the outfit of the Volta Galvanizing Co. was moved from Pittsburg to Apollo, Pa. where the consolidated Company commenced the manufacture of the now famous brand "Apollo Best Bloom," which is at present made by the American Sheet and Tin Plate Company at the works in Vandegrift, Pa.

Until the middle of the nineties galvanized sheets were produced by dipping the sheets by hand, in large oblong iron kettles or vats filled with the molten metal, using as auxiliary machinery only block and tackle or light cranes to pull the sheets out of the bath. Since then the roller pot, that is a kettle with semi-circular bottom filled with molten metal through which the sheets are drawn by means of several pairs of rolls has taken the place of the old hand dipping process.

The art of tin plating is about five hundred years old, it was first invented in Bohemia or Saxony near the Ore Mountains where the process was kept a secret for a long

time. Germany and England used large amounts of the small tinned plates for warriors' armatures, church steeple roofing, and fancy ware, and pieces of such ware were kept as heirlooms from generation to generation.

The first account of tin plate manufacture in England is found in a book written by Andrew Yarranton about 1680. This gentleman had been over in Bohemia and learned the secret and built a small works at Pontypool, Monmouthshire, but no real success seems to have been achieved until about 1728, when as said before the rolling of black plates was invented; and by that means England gained supremacy in the industry. There still exists near the cradle of the industry in Bohemia, Moravia and Styria, tinplate works where excellent old-fashioned plates are produced.

There are also tin plate works in Westphalia, Rhenish Prussia and France, where in recent years the industry has made much progress; but strange as it may sound the manufacturers there only achieved their real success after their delegates had been in the United States, and had seen the many improvements and new devices which the American manufacturers had introduced or were introducing immediately after making the start.

In this country that start was long delayed and held up by handicaps and intrigues, but after it did get a fair start it spread so rapidly that you could actually see it grow. Up to 1890 the production was insignificant; in that year the McKinley tariff bill was enacted and tinplates were granted protection the same as the kindred branches of the iron industry which had enjoyed protection for generations, but while the bill generally became effective on October 1st, 1890, the paragraph relating to tinplate did not become operative until July, 1891. In that year we made in this country approximately 12,000 boxes, in 1898 the production had reached 3,600,000 boxes. What the production is at present I do not know, but I estimate that it is not much less than ten million boxes per annum. I fear I am taxing your patience and must therefore refrain from going into the details of the long strug-

gle and the many hardships we pioneers had to overcome, the long and laborious fight we had to remove the obstacles which were placed in our way by the English manufacturers and their allies the American importers—and especially to combat the ignorance of our people, very few of whom knew thirty years ago what tinplates were composed of; most of them imagining that tinplates were made from the pure tin instead of being iron plates covered by a thin coat of tin; and this ignorance was mainly the cause of preventing an earlier development of that industry in this country. It may not be known by many of you, who think that in the good old times the people knew nothing of graft, that the erroneous (?) misplacement of a single little comma was the reason that during the twenty-five years from 1866 to 1891 the United States had to import a round five million gross tons of Tinplates, at the foreign value of about five hundred million dollars exclusive of freights and importers' profits. The story of the comma is this: When the Morrill tariff bill was passed in 1864, it was clearly the intention of the law makers that tinplates or sheets coated with tin (tinplates) should bear the same duty as sheets coated with zinc (galvanized iron) for the respective paragraph read: "On tinplates, and iron galvanized or coated with any metal, 2½c per pound"—but the then Secretary of the Treasury, Mr. Fessenden, under pressure of the tinplate importers, decided that there had been an error in punctuation. The text of his decision read as follows: "It would appear that an error of punctuation has been made by some one, most probably the clerk who engrossed that part of the act; if the comma which is inserted after the word plates be omitted and a comma placed after the word iron, the true sense will be had, which unquestionably is that tinplates as well as the iron must be galvanized or coated with other metal in order to bring them within the provision."

After that tinplates were classed as sheets of pure tin on which the tariff was only 15% ad valorem, when the duty on galvanized or coated sheets equaled about 66% ad valorem.

When we commenced the manufacture in this country in 1873 and 1874 we were ignorant of this decision, for while the U. S. Government collected only a comparatively small revenue on imported tin plates the English manufacturers and American importers managed to put on the tariff and therefore the selling prices which prevailed offered good inducements for an attempt to produce them here—after we had found out later on why the importers were able to annihilate us with their reduced prices we plead and plead with the Treasury Department and with Congress for about fifteen years for a correction of the erroneous decision, and scores of petitions and resolutions were presented to Congress but they were all turned down until Major Wm. McKinley came to our rescue.

But, gentlemen, my paper has occupied too much time already, if any one would like to read more about the early history of the Tinplate Industry, he can find it in a little pamphlet which Mr. John Jarrett issued at the time of the Chicago World's Fair and of which I will leave here a few copies which I happened to find amongst other old memoranda. Regarding a detailed description of the tinplating methods as they are practiced to-day will say that some one of the younger men who are engaged in that industry at present could give you a more interesting talk than I can, at any rate I cannot weary you any longer to-night. I should and would have been more brief in some of my remarks but having only recently returned home after a four months absence I could not find time for the boiling down process.

Gentlemen, I thank you.

The President: I am sure you all agree with me that we have had the pleasure of listening to a very interesting paper upon a subject about which it is very difficult to get very much information; and from a gentleman whose experience enables him to speak with authority upon this subject.

I regret that we will not be able to have Mr. Ellis with us

this evening to read the paper on Sheet Metal Manipulation. He has however prepared a paper which will be read by Mr. F. C. Biggert, Jr., to which we will take great pleasure in listening.

Sheet Metal Manipulation.

BY FRANK I. ELLIS,*

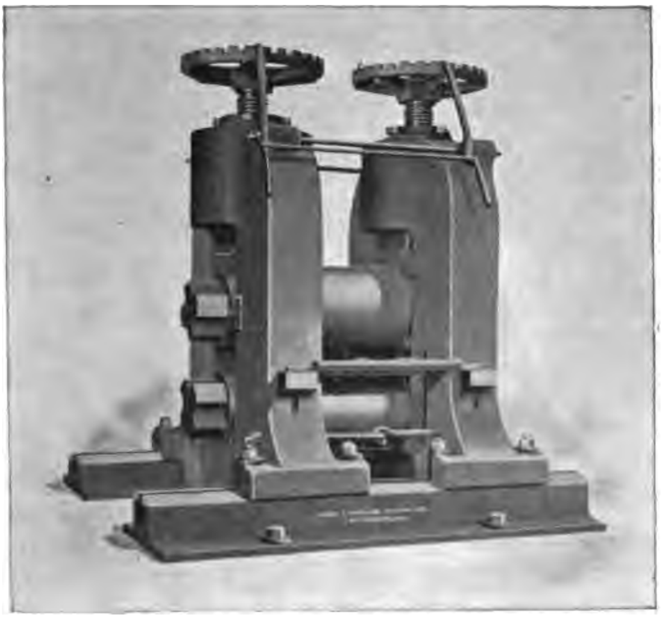
Member.

You have heard a very interesting paper on the rolling of sheet metal by Mr. Cronemeyer, and I have been asked to give a short talk on sheet metal manipulation. It will of necessity be a short talk, as the notice was extremely short. However, the subject is one that has made very little advance within the last fifteen or twenty years. The regular sheet mill with the exception, perhaps of two continuous mills in the vicinity of Pittsburgh are made much like they were in the early days of the Welsh industry.

The writer's first introduction to a sheet mill was in a foreign country where they followed the old Welsh system and had sheet rolls 18 inches in diameter by 24 to 26 inches long. This was essentially a hand mill in every sense of the word, very low production was made and everything was done in the simplest manner. Very little was known of special mixture for rolls or special mixtures for brasses and bearings and the refinements of hot and cold neck brasses. However, the result in product, which was iron sheets, was one that stood the weather and was in most respects a very excellent plate. In the old type of mills the housings very seldom ran over about 13,000 to 15,000 pounds weight each, and therefore the rolling of the sheet took considerable time. The housings to-day are getting nearer to 30,000 lbs., as a common every day weight, although most of the standard sheet mill housings for finishing mills approximate 25,000 lbs. Tin Mill housings are not quite so heavy.

* Chief Engineer, United Engineering & Foundry Co.

Perhaps the wisest way to talk over a subject of this kind would be to start in with the driving arrangement. Much difference of opinion still exists as to whether direct drive, rope drive or geared connections are the better. However, in all cases, in consequence of the very low speed of these mills, averaging about 28 to 30 revolutions per minute, it is necessary to use an extremely heavy fly wheel, this fly wheel ranging from



24-inch Tin Plate Mill.

70 to 100 tons weight. In our own practice we favor and have put in successful operation the direct drive, an example of which is at the National Enameling & Stamping Co., Granite City, Ill., which we believe is the best direct geared drive running to-day. This plant I might say in a few words, is what is known as a 16 mill plant, that is the *new* portion of the plant is, while altogether they have about 25 mills. This 16 mill portion is divided up into two sets of eight mills, each

with the engines central of the mills; that is, on each side of the engines there are four stands of sheet mills. These engines are 30 inches and 56 inches by 56 inches Cooper-Corliss twin tandem compound condensing engines; the fly wheel in this case for each pair of engines being 100 tons in weight, and 30 feet in diameter. These particular engines are giving very little trouble since they were put in and are considered one of the successful cases of direct driving, the Kennedy overhanging crank being used as connection between the mills and the engines.

As you will note by the illustrations submitted, the housings and the stand complete is a very simple proposition, one of the main features to be attained is to get plenty of mass in the mill, the bed plates and housings being of very heavy design. The standard mill where they are using what is known as the heavy sheet bar are arranged to have usually a set of what are called jobbing mill housings nearest to the engine, a set of pinion housings next, one set of finishing, one set of balanced roughing and another set of finishing and then in many cases a set of cold mills. The difference between the finishing housings and the balanced roll housings is mostly in the manipulation, usually the same patterns are used for both, but the arrangement of the fillings and the carriages which carry the roll are different. In the finishing mill the bottom roll is the driven roll, the top roll being driven by friction alone, while in the roughing roll the pinion housings are used to drive the upper roll, which is balanced, and has a movement of anything up to about a maximum of 1¾-inch opening. The rolls in the roughing mill are usually a sand roll and the finishing mills are always chilled rolls, the depth of the chill and the finishing of the roll being very important parts of this work; in fact, the whole responsibility of a good finished plate rests with the finish of the rolls and the structure of the same. You will note by the illustrations that I have handed round, what is known as the depth of the chill. These finishing rolls are usually adjusted by what is known as a spanner wheel on top of the screw. This spanner wheel is turned by

levers which drop into the teeth alternately, while on the roughing mill the usual arrangement is a bevel wheel on top of the screw and the bevel pinion arranged with a line shaft connecting both screws together and operated by a large hand wheel, as you will see in some of the illustrations presented. The plate is passed through on the one side by the roller and on the other side his first helper takes this plate which is guided by strips of steel leading from the rolls to a bracket across the front of the housing, and over what is known as a billy roller. This helps the catcher to pass the

The white line shows the depth of chill.

plate across the top of the rolls back to the roller. In the roughing mills the screw down is operated by a boy who, of course, is under the instruction of the roller. The next essential feature to the roll being properly finished is the question of the brasses for carrying the rolls. These brasses or bearings are made of a special high grade bronze, which is adapted to carry the high heat generated and absorbed from the plate by the neck of the roll, as it is not possible to put water on these rolls and they are known technically as hot mill necks.

All of the cooling except in a few instances has to be done by the grease. This grease is a very essential feature and considerable skill is exhibited by the man in charge of the mixture of same and what is also very important is in the care of it to reduce the cost. Considerable difference exists to-day in the cost of this necessary article, as much as 10c per lb., to my knowledge. The cold rolls, which as stated were in a moderate sized mill, usually placed on the end of the sheet mills, (except in a case, say like the National Enameling & Stamping Co., where they have a separate cold mill department and have separate stands of these mills) are usually 22 inches in diameter rolls by approximately 44 inches long.

Sheet Mills, by the by, were up to a year or two ago nearly all 24-inch Mills, but to-day the regular roll is 26 inches in diameter and some of them are 28 inches. These cold Mills are also made with a heavy housing, but nothing as heavy as the sheet mills, the average cold mill housing running about 13,000 to 15,000 lbs. weight. The housings are made peculiar in one respect, that is, they have two screws instead of one, the object of this being to move the top roll in a horizontal direction out of parallelism with the bottom roll and it is technically known as crossing. This, as you will note, helps to bite the plate in a little out of the uniform thickness, tending to change the character of the finishing, which is one of the features of the roller's proposition. I might say that in sheet mills, to overcome the expansion of the rolls they are also turned slightly hollow,, this hollow turning being done by crossing them on a lathe roll very similarly to what is done with the cold mill double screws. The guides for a cold mill are usually very simple, usually a board to lay the sheet on as it enters the mill and one to guide it out on the other side. In fact the whole proposition of sheet mill handling is very simple as far as the machinery is concerned. In the proposition of rolling sheet plate in contra distinction to tin plate, the plates are doubled by what is known as a steam doubler, in some cases though, and on some of the less advanced mills this steam doubler is not used, but the men

double the plate by manipulations of the tongs and then tramping on it to compress the two edges at the doubling point. The sheet is then put on the doubling shear, the arm of the shear makes the plate double very close and it is trimmed to size on the long knife shear. This is a peculiar machine and the pictures I believe explain its construction better than any description could do. In mills which the writer saw some time ago, and which he mentioned earlier in the talk, this doubling shear was what is known as a long crocodile shear or what is known now as a lever shear. This old shear can be seen still in some of the old fashioned mills

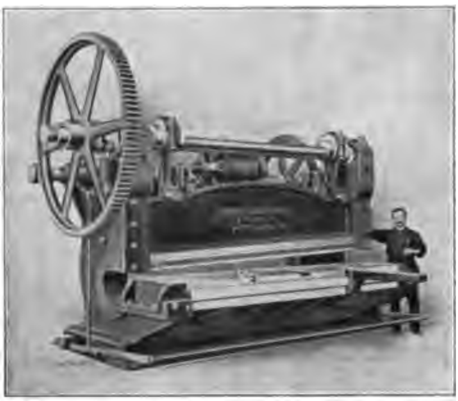
Sheet Mill.

and was driven by a large cam on the engine shaft near the coupling to the mill, the lever arm for the knife on one shear being 18 feet long, the knife itself being about 30 inches. This gives very excellent work but of course was a very primitively designed and simple machine and got out of order a great deal. These are the only machines used in connection with the rolling of plate.

The furnaces, I might state, on these mills are special, as you will no doubt understand, being known as pair and sheet furnaces respectively. The pair furnaces are the furnaces in which the original billets, which are approximately 8 inches by ⅜ inch to 1¾ inches thick, and 24 inches to 40

inches long, are first heated. They are taken out of the furnaces two at a time (hence its name of "pair furnace"), and the roller passes them one after another back through the mill, his helper passing them back to him. As they get thin, and when down to about 1/8 inch thick they are paired, that is, one sheet is placed on top of the other, and rolling process is carried on, rolling two sheets at a time. These sheets are doubled and again doubled, etc., until the proper gauge is gotten to suit the order. This you will see is the only way that very thin plates could possibly be rolled in a hot state, all the plates roll to practically the same thickness and in fact they come out to a certain ounce weight when sheared to size, showing that the rolling is very close. The sheet furnaces are used to re-heat this sheet during the process of rolling, as you will understand the plates go through the mill, and of course, are getting colder all the time, and are re-heated according to the views of the roller. This furnace is located directly opposite the finishing mill, most of the mills having what is known as a long spindle between the finishing stands to allow of this arrangement, as of course, the furnaces take up considerable room and their centers are naturally wider than is necessary for the mills. In the case of the Granite City plant the spindles are 20 feet long. It may be of interest to you to know that these spindles are 17 inches in diameter, of cruciform section, with dimensions of 17 inches, 10 inches and 6 inches. After the sheets are rolled and are cold, they are taken and split apart and the Squaring Shears are brought into use, finishing them to the proper size and to the dimensions called for. In a sheet Mill the dimensions run up to as long as 10 feet and 12 feet, and of a width up to about 44 inches, or according to what the order calls for. These sheet shears are also a simple proposition, but of course have features about them that require special attention. You will note by the pictures the general construction of them and if there are any questions to ask, I will be glad to answer them. This, of course, applies to any of the other illustrations submitted. These shears are also used in some plants for what is known

as re-shearing, that is, where the specifications call for very close adherence to the size of the plate, a shear is used of the squaring shear type, but with very much better hold down and more exact gauges for cutting the plate exactly to size. Another furnace that I might mention is known as an annealing furnace, to which the sheets are taken to be annealed. These furnaces are usually of the type as shown on the blue print and the sheets are placed on top of what is known as the annealing box bottom. As you will note by the rough sketch on the blackboard the tracks for these bottoms (which are really carriages) are a hollow groove in a casting placed



126-inch Squaring Shear.

in the floor, the bottom having the same hollow groove in its lower side and cast steel balls averaging 7 inches in diameter are usually used for bearings for rolling these bottoms into the furnace. Before doing so the plates are piled on top of it and a cover, which is known technically as the annealing box, is placed over them and a sand joint made all around between the box and the bottom. It is then placed in the furnace, the temperature of which is raised to about 1,800 degrees and the doors closed and properly sealed and the annealing process follows. The ordinary process of charging these annealing

boxes is by using a chain and attaching to the crane. There is also another method of putting them in the furnace, in which the sides of the furnace are raised to a higher level than the bottom and a machine known as a Freeman charging machine is used, this machine being arranged to carry the bottom and the box into the furnace and then by relieving device lowers them down on to the side walls in the furnace, the machine then being withdrawn. This is a very handy device and works very well indeed. As far as sheet mills are concerned, this is the complete method of handling the sheets. Of course, galvanized and corrugated sheet for roofing goes through further processes, which might be touched on in a general manner. They are passed, after annealing, into the galvanizing room, where, when properly cleaned by acids, are passed to the galvanizing pots, which I have brought one or two pictures of, and from this pot are taken out, put through a leveling machine, are ready for corrugating or shipping in the flat state. The corrugating machine is also a comparatively simple roller machine as it is mostly used. There is also another machine, in which the corrugations are stamped. The illustrations of the corrugating machine shown does not show the automatic feeding table which goes with the machine and which is arranged to feed the plates squarely into the corrugations on the rolls. For your general information I would state that this machine will take in any standard gauge plate made, up to a length of 10 feet.

Tin Plate manufacture is very much on the same lines as the sheet mill, the same type of housings, the same method of manipulation, except that the doubling shear is seldom used. The furnaces are similar and the process is very much the same, except of course, they go from a smaller billet thickness, being as thin sometimes as ⅜ inch, and down to a thinner gauge for other finished material. After being rolled they are taken to the tin pots (of which I have no illustration convenient to show you) and the coating of tin is put on. There are a number of tin pots in use, but I believe the Morewood is considered one of the best types, although I have not done any-

thing in the tin plate business for some years and have perhaps lost touch of what is being done.

I hope this will give you a slight insight into the general features of sheet mill manipulation and await any further questions you may ask.

DISCUSSION.

The President: Gentlemen—We have had the pleasure of listening to two very interesting papers, and I have no doubt that points have been suggested that will serve as a basis for considerable discussion. The paper is now open for general discussion.

Mr. Biggert: I have a little data here that might add to that in regard to the production of tin mills and sheet mills. The tin mills up until the end of 1905, January, were working under limited output on account of the Unions. Up to that time they rolled 30 gage, 200 pairs; 31 gage, 272 pairs. That would be 5,200 and 6,800 sheets in an eight hour day. After that they rolled full days with 28 gage would be 900; 29 gage about 1,800, and so on, up to 33 gage they rolled 7,360 plates.

Heating the rolls is still a limiting feature. If they roll too hot the necks get so hot they can't get proper lubrication and the rolling of course has to cease until the rolls get cooled down.

In a 26x44 mill they run from 11,500 to 12,000 pounds in a day. And the American Tube & Stamping Company have rolled 14,000 pounds of 20 gage 96x44 plates in a nine hour day.

Frederick W. Winter: Mr. Cronemeyer referred to the process of annealing on the fire bed. I would like to ask Mr. Cronemeyer this: I have heard that term applied to certain gages of sheets, somewhat too thin to be called a plate and too thick to be called a sheet. I have always been curious to know why the term "fire bed" should be used to designate gages of sheet metal?

One other thing: I would like to know if Mr. Crone-

meyer has any information as to about the time when the stamping and enameling companies substituted sheet steel for sheet iron for those purposes?

Mr. Cronemeyer has also referred to the fact that their plant at Demmler has always been open to the student. In 1897 I came to Pittsburgh for the first time and visited a large number of iron plants. One afternoon I dropped into the works at Demmler and I wish to bear testimony that Mr. Cronemeyer's statement is exactly right. We found the plant shut down except the tinning department, but found Mr. Cronemeyer very courteous and only too ready to explain anything that we wanted to know. We were shown all over the plant and by the time we left we had acquired a considerable information as to the manufacture of sheet and tinned iron.

Mr. Cronemeyer: In regard to the term "fire bed" I believe it originated from the fact that in mills where they did not have separate annealing furnaces, sheets up to No. 20 gage were annealed in the same furnace in which they had been heated during the rolling process. The bottoms of these furnaces were covered with a thick layer of coke, which when the furnaces were heated formed a glowing bed of fire. On this bed of fire packs of sheets were placed, and after doors and dampers were closed were left to anneal; hence the term "fire-bed." Whether my interpretation is altogether correct, I do not know; the term was already an old one when I engaged in the sheet iron business, but I have always believed that it originated as I have explained.

In answer to the other question, in regard to the introduction of steel into the manufacture of enameled ware. When enameled ware was first made in this country by the Niedringhaus people in St. Louis, they had a process which did not take to steel. Their ware was all coated iron. That process was kept up for a long time. They encountered severe competition by the Lalance & Grosjean Mfg. Co. who had commenced the business at about the same time. The Niedringhaus Co. gained a law suit against the Lalance & Grosjean

people for using their patents. Previous to that the latter had manufactured what they called "agate ware." After that they called it "marbleized ware." A little later; I cannot state the year exactly but I think it was 1886 or 1887; the Iron Clad Manufacturing Co. commenced the manufacture of enameled ware and used steel. The latter got their process from the works at Thale, Thuringia in Germany or Eckesei, Westphalia, where enameled ware had been made out of steel probably five or six years before. And after the Iron Clad Manufacturing Co. had started the stamping of steel and coating it with their enamel the Lalance & Grosjean Mfg. Co. and other works which were built, also used steel, and then the industry grew very rapidly in this country. The Niedringhaus or St. Louis Stamping Co. consolidated with several other companies and the National Enameling & Stamping Co. was formed. At present there is probably more enameled ware produced by outsiders than by the consolidated company. All use steel now. Possibly both the Niedringhaus and the Lalance & Grosjean people still use some iron occasionally.

L. A. Starrett: The gentleman who read the last paper read a statement that the diameter of the rolls was increased. Was that for the purpose of increasing the output or the speed of the rolls, or was it to keep the output the same and thereby reduce the number of revolutions on the bearing?

Mr. Biggert: The only reason for enlarging was to save breakage of the rolls. The pressure is enormous in rolling steel sheets, or iron either, and the breakage of the rolls is a very big item in the cost of manufacture. That was the reason for making them larger, and they are going now toward 28 inch mills rather than 20 inch. I believe the Bray mills are 28 inch. That is the new continuous mill about which Mr. Cronemeyer spoke.

There is no less friction loss on the bearings as the necks were changed from 18 inches to 20 inches diameter at the same time the rolls were enlarged.

It is not desirable to reduce the number of revolutions as the mills run only about 28 revolutions per minute, which re-

quires either gearing or very large engines. Twenty-eight revolutions is a very slow engine.

J. L. Klindworth: I, too, have grown up in the industry of the tin plate, you might say, though I have been away from it now for a good many years. But as I recollect they increased the roll diameter for the purpose of obtaining greater radiating surface. As Mr. Biggert has stated, you must not roll too fast or you will heat the rolls too high; and by having larger diameters you get greater circumference and increase the radiating surface. Then, of course there is quite a gain in strength.

Mr. Biggert: Your chilled roll is not very strong. The centre has to take all the strength. Chilling takes away the strength of from 1¼ inches to 1½ inches all around the roll, and of course you have to depend on the centre of the roll for your strength. Then the pressure is so great, and it gets alternately heated and chilled time after time, so that it starts cracking. And as Mr. Klindworth stated, in the increase from 24 inches to 28 inches you would get an increase of about 8% in surface.

Mr. Klindworth: I might add that to me it seemed remarkable how the Americans developed the industry. They had been going on in the old country for a hundred years, as Mr. Cronemeyer stated, with their small mills, but as soon as the Americans took hold of it they increased the diameter of the rolls from 18 inches and 20 inches to 24 inches. They started in with 20 inches but only for a short time. I was then with the Robinson & Ray Mfg. Co., and when they increased the Tin Plate mill to 24 inches we had to plane out the old housings for the larger rolls, and all within, you might say, one year's time.

Mr. Cronemeyer: Mr. William Banfield, of the firm of Wallace and Banfield was the first man who increased the diameter.

Richard Hirsch: I would like to ask a question in regard to the breakage of large plate rolls; that is, if the failure is not largely due to internal strains and alternate heating and

cooling, as well as to the actual stresses under which the rolls are working? Would also like to ask if it has ever been tried, or if it would be feasible to cast a roll hollow, thereby more uniformly distributing the internal strains, avoiding possible sponginess in the interior of the casting, and at the same time obtaining a radiating surface for cooling the interior of the roll?

Mr. Biggert: That has been tried on plate mills, but it was never a success because they never got the rolls to stand up. Instead of having segregation in the middle of the roll you have it in a ring around the hole in the roll, where it is more effective in breaking than in strengthening the roll. Also you cannot core out the hole on the inside, you have to have just a small hole and it makes a non-uniform cooling effect. They never had very good success with this type of roll.

A Member: Why don't they run water through the brasses? That ought not to hurt the roll.

Mr. Biggert: The reason for that is the great pressure. The pressure is so great on the brasses that they break anyhow after a comparatively short time. They break right through the middle even though they are held in a close fitting.

H. C. Babbitt: Have they ever tried manganese steel or anything of that kind for rolls?

Mr. Biggert: They never have tried anything of that kind so far as I know except chilled rolls. There is nothing that will give the surface.

Mr. Cronemeyer: It has been tried by Jennings, Beale & Co., at Leechburg but with no success. They were not successful because the material lacked the chill and they could not get the qualities possessed by chilled iron rolls.

Mr. Babbitt: Manganese steel is always what you might call hard, you cannot dent it with a peen hammer. But I think there would be trouble in turning up these rolls, you would have to grind them.

Mr. Biggert: Manganese steel that has been forged.

You do not mean steel castings? With a casting can you get a perfectly uniform density?

Mr. Babbitt: One of the peculiarities of manganese steel is this. Suppose you take a 1 inch screw as it is cast and strike it with an ordinary hammer and you will break it. Heat that to a white heat and plunge it into water and you can bend it 90 degrees, and yet it has not lost its hardness. And it is very uniform. In the few castings I have made several years ago for a sort of semi-armor plate, I found that a steel with about from 12% to 14% manganese would live longer in the ladle and naturally would run into a finer mold than the very softest of cast iron, and yet it was hard. And that is one of the peculiarities of it. Take a 1½ inch shield plate for a gun: A 6 pound shot fired against it would shatter it in its natural state; but after you had tempered it, as you might call it, heated it to a white heat and plunged it into a water, it would shatter the shot.

Mr. Biggert: If it could be done it would be a good thing to try.

Lee C. Moore: I would like to say, apropos of rolling tin plate that high grade steel wire is rolled with cast steel rolls. They are forged in the form of rings and turned and ground on the inside, then forced on the mandril and turned up on the outside as near to diameter as possible, and then tempered. And the tempering process is probably the secret of the life of the roll. It is made as hard as it is possible to make them. Then after that they are ground and then again taken from the mandril, reground, and put on the mandril that is intended to go on the rolls, and with that pair of rolls they can roll steel as high as .90 down to as thin as .006 inch.

I might say in this connection that the Frenchmen roll this high grade steel down to as thin as .002 inch: .006 inch is, I believe, the thinnest we have ever gotten in this country. It is so thin I cannot describe it. That is cold rolling entirely.

A Member: I would like to inquire if they have very much trouble in getting that steel to uniform thickness when they get down to such thin diameters.

Mr. Moore: I should have said that I referred to only very narrow widths, something like 5-16 inch, although the Frenchmen roll wide sheets, to the width of 4 inches. It will not vary over ½ of 1-1000 inch in thickness.

Mr. Babbitt: We are using an iron wire that is 17-10,000 inch in diameter.

Mr. Cronemeyer: As regards rolling down to .006 inch, that is now a very common proceeding. The product is called Taggers and of that there is a great deal used at the present time. They roll it by forming sixteen sheets into a pack, and when such pack is rolled down to the required weight per foot, the single sheets are pretty uniform in thickness. The pack is formed by doubling and doubling again. It is generally rolled in sheets 20 inches by 56 inches and cut into smaller sizes afterwards. I have seen Taggers rolled in size of 28 inches by 84 inches down to a thickness of .006 inch.

Before the Mechanical Section, February 5, 1907.
CHAIRMAN SUMNER B. ELY, PRESIDING.

Some Late Improvements on Compressive Riveters and Other Tools.

BY CHESTER B. ALBREE.*
Member.

Next in order is the paper of the evening, by Mr. Chester B. Albree, and we will be glad to hear from him.

Mr. Albree: When it was found out the other day that the paper we had expected to have this evening could not be prepared in time and we would be without anything to work on at all, Mr. Moore stated to me that he would make his annual address, and asked me if I would not say something about some of the work we had been taking up recently. In compliance with his request I may say that I have prepared nothing whatever, but I'll simply talk off-hand, and I wish you to accept it in that way: and I will do my talking on the blackboard. I would say in relation to riveting machines and pneumatic tools, which we have been engaged in manufacturing for several years past, that I read a paper on pneumatic hammers before this Society, and later one on the designing of riveting machines; and my remarks this evening will be on some new features in the same line of work.

COMPRESSIVE RIVETERS.

In compressive riveter work there are two or three types which are quite familiar, the oldest type being the straight hydraulic machine invented by Tweddel in England, and later on, the pneumatic riveter by Allen of New York, who was perhaps the first to make it a success. Later came the hydro-pneumatic riveters. With the hydro-pneumatic riveter we have been making some experiments, and it was found to be advisable for several reasons, notably for greater economy of

* President Chester B. Albree Iron Works, Pittsburgh, Pa.

air, simplicity of construction and better action; to try to improve the methods that had been in use. In driving rivets the pressure required differs from punching materials in that in punching, your greatest pressure comes at the first of the stroke, when the punch comes down on the material. In riveting, however, especially hot riveting, the easiest work is when the die first strikes the rivet and the greatest pressure is required to finally form the head. That being the case it can readily be perceived that a constantly increasing pressure would be the theoretically correct pressure to drive rivets.

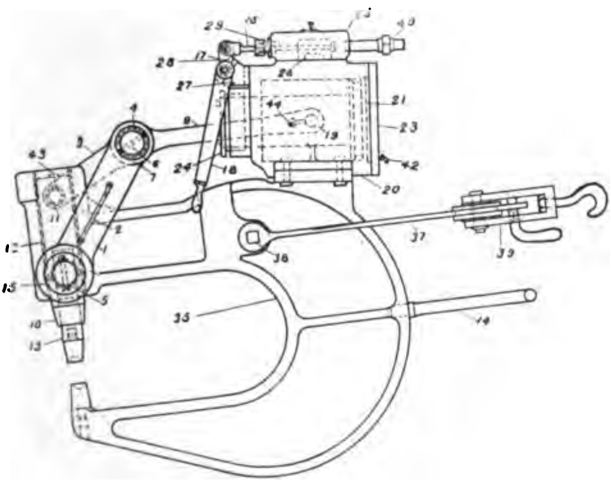


FIG. 1.

This pressure is most easily obtained by means of the toggle joint, which theoretically gives an infinite pressure with an infinitesimal movement at the end of the stroke. In practice, of course, we do not get an infinite pressure; but, as most riveters are of horse shoe or yoke type, the limit pressure is the yielding point or the bending point in the yoke. In straight toggle joint machines the general idea is shown in Fig. 1.

In practice we find that when the cylinder has made seven-eighths of its stroke the pressure line of the rivet dies rises

up to about 15 times the pressure in the cylinder. By that time we would have traveled within about 1-16 inch of the final stroke of the machine, and beyond that point the probabilities are that there would be spring in the yoke. If we made the yoke strong enough not to spring at all, it would be so heavy as to be utterly unmanageable. So it is only necessary that deflection should not occur at a pressure below that necessary to drive the rivet. Hence in the toggle joint arrangement we have the best possible arrangement for driving rivets.

But there are certain drawbacks in the practical application of the toggle pressure. The principal one is that its stroke is absolutely fixed. It never varies for a given leverage. In riveting you are liable to have 1 inch or 2 inches, or maybe only ½ inch thickness of plate and in order to have the maximum pressure just as the die comes to the surface of the plate it is necessary to adjust the distance between the die and the point of maximum pressure by means of a screw actuated by hand. In work that does not vary it makes little difference, but in ordinary structural work, and boiler work, you have constantly to drive rivets through different thicknesses of material, and each time it will be necessary for the operator to adjust the screw. That requires a certain amount of skill, and if it is not done correctly the chances are that you will not drive the rivet sufficiently tight, if you do not close it with maximum pressure.

To overcome this difficulty of adjustment the hydro-pneumatic machine was devised, which is nothing more nor less than a hydraulic intensifier. The ram alone gives a very small but powerful motion, and it is necessary in riveting to have clearances, in order to go over angles, stiffeners, etc., so it is desirable to have a longer stroke. Of course we do not need high pressure over a longer distance than, say 1¾ inches. The question then was how to get a clearance movement. This was accomplished by putting a little extra cylinder below the air cylinder. The air pressure acting on its piston

forces liquid into the ram cylinder at low pressure, and by this means we get 3 or 4 inches of preliminary adjustment.

The objections to this form are in the first place: that it is very difficult to pack, and second, that in order to get two inches of die motion with a maximum pressure of 50 tons, it requires a 15 to 20 inch stroke in the air cylinder, and a very high pressure throughout this stroke in the ram cylinder and plunger cylinder: sufficient for the final closing pressure, thus wasting power. The practical advantage is that it does not require skilled workmen to adjust the dies; they adjust themselves. It occurred to us that we might get the desired toggle joint effect and yet have an automatic adjustment, and what I want to speak of is the device for the accomplishment of this, which may be of interest to you.

In Fig. 2 is shown our first attempt and also our perfected form. As far as the toggle joint action goes it is practically the same as the first machine described. The pressure from the toggle, in the first form machine, is transmitted from the large area of the plunger to the top of the ram and also through a pipe to the adjusting cylinder. The ram being smaller in area and free to move, advances more rapidly than the plunger and continues until the rivet die on its extension strikes the projecting rivet. As the plunger continues, the pressure in the cylinder is limited by the pressure due to the spring in the adjusting cylinder, which is only 20 lbs. per square inch, insufficient to upset the rivet beneath the ram. Hence the liquid will now displace the piston in the adjusting cylinder, the ram remaining stationary. As soon, however, as the projection on the plunger enters the ram cylinder the full toggle pressure is transmitted through the incompressible liquid to the ram; forcing down the rivet; and the differential area above forces the remaining liquid in large plunger bore, into the adjusting cylinder.

During the downward motion of the ram the liquid beneath it is forced into the opposite end of the adjusting cylinder; against the spring pressure. It is obvious that the ram may move its whole adjusting stroke, or none at all, up to the

time that the projection on the plunger enters the smaller area; after which the further travel of the ram is that of the plunger, until the ram meets opposition greater than the pressure of the toggle; when it will stop. This arrangement, therefore, automatically adjusts the point of maximum pressure to suit the work. On the return stroke we have the direct pressure

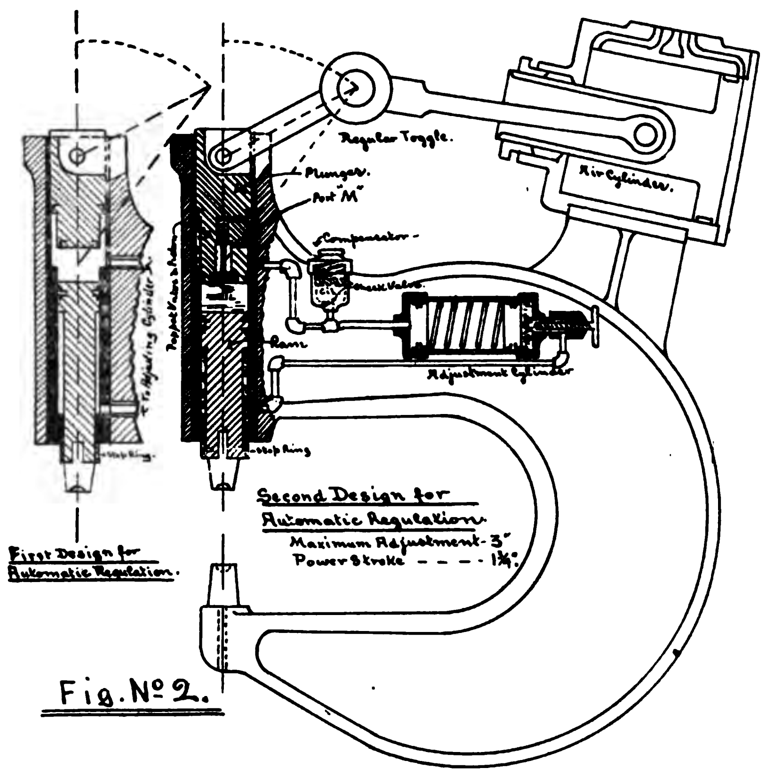


Fig. No 2.

beneath the ram, as well as the suction of the plunger, to raise the ram to its original position.

Theoretically this design was correct, and it worked very well indeed for about two strokes. At the end of the second or third stroke our packing was gone and we have found it impossible to hold the pressures. The trouble lay in the fact

that we put cup leathers at the end of the plunger, and when the cup leathers entered the chamber, the moment the pressure rose to a high point it tended to cut the leather right out. So in order to make the device practically, as well as theoretically successful, it was necessary to devise some scheme to have the leather cups, which hold better than any other hydraulic packing, move always surrounded by the walls of the cylinders, and pass no ports whatever. To do this and yet allow the liquid to pass freely from the upper to the lower part was rather a difficult proposition. We accomplished it in this manner.

Referring to the later form in Fig. 2 it will be noted that the extension of the plunger, when fully up, projects into the smaller area of the ram cylinder; and that cup leathers are used to pack it. In the interior of this extension is a valve of the poppet type, but having a stem carrying on its end a small piston. This valve is normally held open by a spring. So long as the pressure above and below this small piston is the same, the spring holds the valve open, but when the pressure below is greater than above the piston will move up, closing the poppet valve. This occurs only when the port **M** leading into the space below the small piston is closed; due to its passing from the large diameter bore to the smaller ram bore. When closed, the toggle pressure acts on the liquid below the plunger extension, raising the pressure sufficiently to move the small piston and connected valve; and later exerting very high pressure on the poppet valve; shutting it perfectly tight. The adjusting action is precisely the same as in the first type, except that the liquid flows through the plunger extension instead of around it, during the adjustment part of the stroke. With this arrangement it will be noticed that all of the plunger and ram packings are continually enclosed by cylinder walls and pass no ports or openings, so that the packing leathers are not injured. I would say that the adjusting device is patented and the poppet valve device is now being patented.

In any device of this kind there is always a certain loss of

liquid due to a film in the ram (although theoretically the quantity of liquid is constant) and in the course of a little while there would be a partial vacuum inside and pressure on a cavity would not give good hydraulic pressure on the rivet. It was therefore necessary to provide a constant source of supply of the liquid, so arranged that when the pressure rose in the confined liquid it would not blow out, but when there was a vacuum in the system additional liquid would run in.

This loss of liquid is made up from a small storage, or compensating cylinder, full of liquid; having a piston with a spring behind it, connected to the larger bore of the plunger by a pipe, having a check valve in it. Whenever there is pressure in the plunger cylinder the check valve remains closed; but when the toggle is fully back, and the piston in the adjusting cylinder is against its cylinder head, so that no pressure due to its spring is exerted on the liquid, any loss of liquid will tend to create a vacuum in the plunger cylinder, and then the check valve will open and oil flow out of the compensating cylinder, under the pressure of the spring acting in its piston, to replace that lost.

PNEUMATIC HAMMERS.

There is one other little thing I thought I would speak of. We have been working on pneumatic hammers and we have now perfected a hammer and there are one or two features about it which are novel and I think you will be interested in. In pneumatic hammers of nearly all makes, one of the sources of trouble has been that if the workman picked up the hammer and put his finger on the trigger when there was no chisel or rivet set in it, the piston would begin to reciprocate, not having any tool to strike at the lower end it would strike the cylinder head; and in a matter of a minute or two it would smash the piston or cylinder. About 75 or 80% of the breakages of pneumatic hammers are due to carelessness of the workmen in pressing on the trigger when there is no work to do. In other words the little piston strikes the cylinder head

with very disastrous results. We have devised a method of obviating this trouble that is very simple.

The admission port is located near, but not at the end, of the larger cylinder bore. When no tool is placed in the end of the hammer the lower end of the large piston diameter passes and closes the admission port, thus preventing air from acting upon the differential area to lift the piston. Any compressed air below the large diameter escapes by a small leakage port to the exhaust; and this leakage port is only open when the admission port is closed. In hammers actuated by valves exterior to the piston, it seems impossible to use this device, and attempts have been made to mechanically close such valves, but they do not appear to be very successful. The same effect is obtained, but at the expense of loss of

FIG. 3.

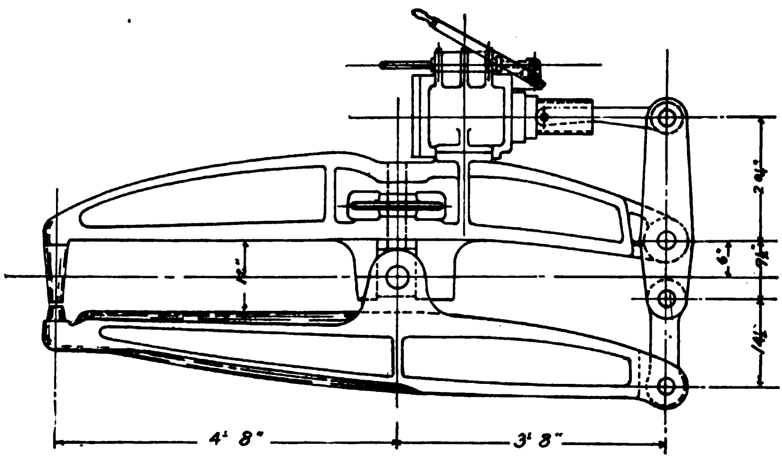
air, when the leakage port is designed to open when the piston is at the extreme end of the stroke, but does not close the admission port. Patents are now pending for these improvements.

This very simple device is very effective. We can pick up a tool and with 100 lbs. air pressure in the pipe, put your finger on the button, opening the throttle, and it does not start unless the tool is fully in place, whereas with all other tools that I know of, the moment you put your finger on the trigger it begins to work, and it is only a question of a few minutes until it is good for nothing.

A SPECIAL RIVETER.

I might speak of another machine that has a feature of interest, that was built for some special work. The work to be done was the riveting of some concrete mixers, they being

in the shape of two cones placed together. The problem was to reach into a very limited space and drive the rivets. They had been doing it by hand and wanted something a little quicker than the pneumatic hammer and something that gave tighter rivets, and wanted a power machine. It was necessary to have a reach of some 50 inches and we had an extremely small opening. At the same time it was necessary to be able to adjust for different thicknesses of material, and to give what we call an alligator motion to the jaws of the machine. The ordinary riveter could not be used for this work.



Alligator Riveter—
Fig.—No. 4.

To secure adjustment of the projecting alligator jaws of the machine, we inserted a screw carrying the trunions of the fulcrum on one end—a hand wheel, with thread in the hub, serves to raise or lower the screw—thus adjusting the distance between the ends of the jaws as desired, and at the same time not interfering with their clearance or action.

The details of the machine are plainly indicated in the cut—it is provided with a Universal Bail, so that it can be used in any plane at any angle.

We also designed a special carriage to hold the double

cones, rendering it unnecessary to raise either riveter or cones, but only to revolve the cones on their axis.

I might mention one other thing that I believe will not be quite new to you because a little description of it was published in some of the technical papers, and that is a horizontal method of riveting boilers. We made a wheeled truck carrying on its bed three sets of rollers running the opposite direction. We suspended from a trestle a riveter large enough to do boiler work, from a bail attached through a system of sheaves and tackles to a counterweight of one-fourth the weight of the riveter and having four times the travel. Then all that was necessary to do was to have a small chain block on the trestle to overcome friction of the sheaves and tackle. In that way we could raise this machine with a chain block for any diameter of boiler.

We have in very successful operation a machine with a 10ft. 6in. gap, weighing about 25,000 lbs. We are now installing several other machines of this character and it seems to be quite a feasible plan. It has several advantages over the ordinary Tower system. It takes up very much less room and the initial cost of installing the plant is very much smaller. This system requires no hoisting of the boiler, as it is simply rolled on the floor or on the rollers. Thus the power plant of the machine is limited to that necessary to actuate the toggle.

DISCUSSION.

The Chairman: I think we have had a very nice talk from Mr. Albree and anybody who is informed upon machinery will certainly know the difficulties they will run against and appreciate the persistence of Mr. Albree in order to bring these things to perfection. Any discussion is now in order.

A. Stucki raised the question that the adjusting device of the riveter described takes care of the difference in the thickness of the sheets, but that it does not compensate for the difference in the length of the projecting rivet ends or the equivalent travel in the upsetting, in other words, that when-

ever this travel is less than the stroke of the machine, the riveter cannot complete the stroke nor exert the full pressure. Mr. Albree confirmed this and stated that their machines are usually built for a 1⅝ inch stroke, which was found sufficient for ordinary structural work. In special cases, he said they would allow somewhat more and provide 1¾ inches travel to take care of rivets up to 1¼ inch diameter and 6 inches grip.

In answer to other questions asked, Mr. Albree stated that the piston of a pneumatic hammer should not be ground in too tight, else burred edges, oil and grit would surely cause trouble in course of time.

Gerald Flanagan: Do I understand you that you never construct but for 1⅝ inches?

Mr. Albree: For ordinary work, no. For very large rivets we would have to build a machine to fit, but for any ordinary structural work, 1⅝ will answer. Supposing the rivet to be driven is to be an ordinary round head rivet. The power travel of the machine is not the length of the rivet but the length from face to face of dies after the unformed shank of rivet touches the recess in face of the die. You cannot go any farther than the material will allow; and having the formulae for length of rivets for large grips, I think you will find that 1¾ inches will be ample to drive any rivet up to about 1¼ inches diameter for any grip up to 6 inches.

P. S. Whitman: I would like to ask Mr. Albree why it is so much more difficult to get a tight rivet when you have a 3 inch grip than when you have a 1 inch grip? I have had some experience with end stiffeners with heavy plate girders, where you have a grip of 3 inches or 3½ inches, and it is almost impossible to get those rivets in tight. Has that anything to do with the machine, or is it due to the fact that when the hot rivet enters the cool metal, it cools off?

Mr. Albree: There are two or three reasons. In the first place when a rivet is upset, especially in a long hole, it is pushed from one end. The lower end is stationary in the die, and the movement is all from the top; the metal has to flow from the top down. Theoretically we should fill the

entire hole. When the rivet is first put in there is an allowance of 1-16 inch in diameter of hole to allow the hot rivet, which has expanded, to go in easily. For a ¾-inch rivet you would have a 13-16 inch hole. It is obvious that when the pressure comes down, what we really want to do is to begin to fill the hole space up from the bottom. What actually occurs is that we begin to fill the hole at the top; when the rivet begins to buldge: and when we finally form our rivet, the bottom of the hole is not filled. With a 1¾ inch rivet through 4 inches of metal we made a cross section with a planer of the rivet driven in that way, and we have found that the hole would be completely filled at the top and as you go down there is a perceptible space all around the rivet. If we could drive a rivet with pressure at both ends we could fill the whole hole. The filling of the hole is independent of the amount of pressure, but is due to the fact that the pressure is all in one direction.

Another trouble is that if you have a large plate girder; toward the middle of it you will have three or four inches of thicknesses of cover plate, perhaps more than that. You have perhaps ¾ inch plates and angles, maybe 1 inch thick, on them. While they are supposed to be straight they are not absolutely flat by a very great deal; and if we have at this particular point a buckle of 1-16 inch, to exaggerate it, when you come down with your pressure and form your head, your machine, if it is powerful enough and the plates are not too heavy, will squeeze those plates together. If the machine is not powerful enough it will not bring them together. It is not merely a question of squeezing those plates together. Then if you take off your pressure before the rivet has grown entirely cool the spring in the plates is sufficient to stretch the rivet. I have seen it done over and over again. That is not the fault of the riveter but of the work. If the work was all of it perfectly flat you would not have that trouble at all. Therefore in heavy work it is advisable to have an excess of power in your riveter; instead of trying to use a machine with a 10 inch cylinder, use a 12 inch or 14 inch cylinder. We built

some machines for the McClintic-Marshall Construction Co., for riveting plate girders such as these, to drive ¾ and ⅞ rivets, and yet they required 14 inch cylinders, whereas we drive ¾ inch with 10 inch cylinder. But they wanted an extra pressure to squeeze the plates together and hold the pressure on the rivet long enough to allow it to lose its red heat and become cool. It takes more time, but when the pressure is taken off the rivet is cold enough to stand the spring of the plates without stretching.

Mr. Stucki: Have you ever designed a machine to punch as well as drive rivets, on the same machine, without moving it?

Mr. Albree: No, because the toggle joint machine is not adapted for punching, because you get your weak pressure at first and your higher pressure at the end.

Mr. Flanagan: When the manufacturer shows a rivet length for a certain grip, does he simply figure out the amount of material in the rivet necessary to make the head and also to completely fill the hole and publish that, or are those tables published after experiments, allowing for the amount of vacancy which you have just sketched?

Mr. Albree: I do not know how others have done it, but we have published a table of that kind, and in that table I figured out the total volume, that is the volume of metal in the head and the volume of clearance space, and how much length of rivet it would take to fill up that space or volume. And then we made quite a long series of tests to check off our tabulated results and we found they ran very close. If your rivet is burned a little too much or anything of that kind, it would not come out just right, but it is so close that we have used it right along, and a great many works all over the country use it with success.

Mr. Whitman: This is an ideal case. In actual work done in the shops where it is put together and then reamed there are all sorts of cavities between the plates. There is often as much as ¼ inch between the edge of the plate and the rivet, and all the rivets I ever saw cut out, particularly in this

heavy plate girder work, the rivet seems just to bend around the top plate and when you get farther in there is no sign at all that there has been any union between the plate and the rivet.

Mr. Albree: Just as I said, when the rivet upsets it upsets at the top rather than at the bottom. To obviate that there was a Brooklyn concern that had a great deal of very heavy riveting to do that had to be tight. Their grip was I think 3 inches and they were riveted with 1¼ or 1⅜ inch rivets. The rivet was heated to a good bright cherry red and just before riveting the first 1½ inches of the rivet was put in water. That cooled the upper part and left the lower part very hot. Then it was put in the hole and the machine brought down on it and that part was the weakest part. When the machine came together it filled the lower part of the hole and then had enough pressure in the machine to drive this chilled end to form a rivet head. In that case they got perfectly tight work, but most people would not take that trouble. Of course you can see that if the upper end of that rivet were cool enough so that it were stiff enough to transmit enough pressure to make the metal flow in the lower part of the rivet, you could get a tight rivet.

Mr. Whitman: In plate girder railway bridges there is a great deal of trouble with camber, to make the girder accordingly and get it up inside of two or three inches. It seems to me that is caused a good deal by the rivets not being tight; that the plates would give.

Mr. Albree: That is very probable.

Mr. Flanagan: I had a little experience a good many years ago with a man who was not a professional riveter but we had some small amount of riveting to do and wanted it well done. We gave him the full length rivets according to such chart as Mr. Albree speaks of and had occasion to investigate the results later on and we found by cutting one of them apart that the rivet looked a good deal like a corkscrew. It was a very long grip and we went further and found that the operator claimed the rivets were too long, and there being

only a few of them he had cut them off, because with the length we furnished they did nothing but form "soldier caps" on the top of them and he did not want any "soldier caps" in his work. He preferred to have the vacancy in the rivet holes.

Mr. Albree: To exaggerate a little, suppose we have a piece of metal that we want to punch. You give your punch a certain clearance in the die. If you have a good deal of clearance the hole instead of being a true cylindrical hole will be conical in shape. The more clearance you get the more of a conical hole you get. Supposing you have punched a hole conical in cross section, not a straight hole at all. Supposing we put the next plate on that with large end of hole reversed. This is the size your hole is supposed to be, for a ¾ inch rivet it would be 13-16. But it is very often the case that this would be ⅞ or more at that edge of the hole. We do not figure on that in making formulae, we figure on a cylindrical hole. Unless the hole is reamed you will always get an open effect more or less in punching. The thinner the material is the less it is, but when you get metal ½ inch and upward there is a very perceptible difference, enough to make considerable difference in the length of the rivet. That would tend to make the table seem unreliable also.

Mr. Stucki: In regard to what Mr. Flanagan says that depends also on what kind of rivet head you want. I know people who will not accept a rivet head unless it has a shoulder on. They say they do not care for beauty but they want to know you have sufficient metal to fill the hole and then form a head.

Mr. Albree: It has always been my opinion that aside from looks it is not entirely a good thing to make a rivet full hemispherical. The shoulder does not make the rivet any tighter. If you have just enough stuff in there to keep it from shearing off, the filling out of the corners completely is not a matter of utility, it is looks.

Mr. Flanagan: Is the question of the speed with which

you drive the rivet considered? If you drive it very suddenly you may upset the upper end and do no good at the bottom.

Mr. Albree: In the ordinary compression riveter of any type the action is not fast enough to act like a sledge hammer blow at all. In making cross sections of rivets driven by either hand or pneumatic hammer and rivets driven by compression machines of any type, you will generally find that the rivets driven by compression are very much better than the ones driven by either pneumatic tools, or by hand. In other words, driving by blows does not upset the shank of the rivet anything like as well as pressure, and the pressure itself does not do it as well as you could wish.

Mr. Flanagan: The same thing holds good in forging, comparing steam hammer forgings with pressed forgings for certain work.

Mr. Albree: It is the same pressure exactly.

Mr. Stucki: We had a case of this sort, driving the rivet through about 9 inches, and it was essential to have a good fit top and bottom, but inside you could not get a good fit.

Adjourned.

CHARLES DAVIS.

Born at Bridgeton, Bucks County, July 11, 1837.

Died February 21, 1907, at his home in Edgeworth, after a short illness.

Mr. Davis was an active member of this Society from its beginning in 1880, and its President in 1894.

He attended Jefferson College at Canonsburg, but enlisted from there in 1861 as a private in the Tenth Pennsylvania Reserves. At the latter part of the Civil War he was in command of a company.

Mr. Davis' career as a civil engineer was laid altogether in Allegheny and adjoining counties. He was at first engaged on railroad surveys and construction of various new lines, centreing in Pittsburgh. From 1867 to 1881 he was City engineer for Allegheny City and acting also as Consulting engineer on local projects of moment; among others on the building of the Point bridge and the rebuilding of the Smithfield street bridge. He laid out the old North Common into a series of parks in Allegheny City; and later, on the part of the county, directed in the building of the first Carnegie Library in Allegheny City.

He was one of the five members of the United States Artisan Commission to the Vienna Exposition of 1873, appointed by President Grant. In 1887 he received the degree of A. M. from Washington and Jefferson College. He was a charter member of our Society. For the 26 years since 1881, Mr. Davis was County engineer of Allegheny county, and he has steadily received deserved credit from the people for the many fine pieces of bridge work over the county built under his direction. He certainly shared with the County commissioners of the time in the very creditable work of building the new Court House. The Memorial Hall project has come before him and the board very lately.

Notable are the many stone arches and abutments erected in the various administrations—monuments to tell for long years of Charles Davis' solid worth as the engineer.

Mr. Davis leaves two sons and one daughter: Charles W. Davis, Ann Davis (Mrs. Thomas Leggate), Norman C. Davis.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIII JUNE, 1907 No. 5

May 21, 1907.

S. M. Kintner, President,
In the Chair.

Process of Coal Washing.

BY SAMUEL DIESCHER,*
Past President.

Long before the process of coal washing was initiated, lead, copper, silver and gold ores were being washed to eliminate as much as practicable the mere rocky matter and thus concentrate the metallic content of those ores. From this was derived the term "concentration" as used in metallurgy, in connection with this operation.

The washing of coal came with the use of coke for smelting purposes, particularly in blast furnaces. On the European continent coal washing was practiced about seventy-five years ago. It had to be resorted to because of the large percentage of impurities combined with the coal mined there.

IMPURITIES IN COAL.

Bituminous coal contains, besides volatile matter and carbon, ashes and sulphur; both of these latter ingredients are undesirable in the process of iron smelting.

* Consulting Engineer, Farmers Bank Building, Pittsburgh, Pa.

The ashes are partly in the form of slate and partly, but to a smaller extent, in combination with the pure coal. Some of the slate is in pieces by themselves and some remains attached to coal. It is impracticable to pick all the slate from the coal as it comes from the mines, for although large chunks are easily noticed and thrown out, yet there is always a large quantity of that stuff commingled with coal, and is in too small pieces to be removed by hand. The same is to be said in relation to the sulphur as far as it is in the form of iron pyrites. But as both these minerals are detrimental to the production of pig iron, it is necessary that means be employed by which they can be eliminated from the coal prior to its conversion into coke.

The wet concentration of various ores by means of hand screens was practiced centuries ago in European mines. Later on, the screens were enlarged and operated by the aid of mechanical contrivances which made the task of operation less laborious. Hence the art was already known when the use of coke in the smelting of iron ores was initiated and it was found that the coal mined (on the continent of Europe) was not pure enough for the intended purpose. The adaptation to coal of the means employed in concentrating ores was but a step and thus came about the art of coal washing. The German iron industry could never have reached its present state of development if it had not been for the purification of the coal by the washing process.

By crushing the ore, preparatory to its being washed, to sizes not exceeding ¾-inch cubes (or even to smaller sizes) the slate and iron pyrites are split off the coal and if thereafter the coal is put through the washing process the slate and pyrites are separated from the coal to an extent that makes it well adapted for conversion into good blast furnace coke.

Sulphur occurs in the coal also in combination with lime, as gypsum, which is very difficult to eliminate by the washing process, because that mineral is generally shaped like fish scale, resembling flaky mica, owing to which it is all sur-

face, without enough substance to make it sink in water. Another form in which the sulphur appears in the coal is in combination with organic matter. This latter combination cannot be affected by any mechanical process.

The sulphur occuring as pyrites is to a large proportion roasted out in the coke oven but the other two combinations of it remain with the coke.

Another mineral occuring with the coal in larger or smaller proportions that contributes to the percentage of ashes, is what the miners call "bone." This is a combination of earthy matter and bitumen; the more it contains of the latter, the nearer it comes to coal in both appearance and specific gravity. Some mines contain very much bone, others again scarcely any. The nearer its specific gravity is to that of coal, the more difficult it is to get rid of by washing.

The greater the percentage of ashes and sulphur in a coke the smaller is its market value. Sometimes any grade of coke finds takers and at other times only pure coke is in demand. As the contents in ashes increases so also does the quantity of limestone that must be put into the furnace. It takes two pounds of limestone for every pound of ashes in the coke, and then again it takes coke to melt that additional limestone.

Limestone must be added also to induce a combination with the sulphur in the coke; the quantity of limestone required for this purpose is small, but there remains that evil that not all the sulphur enters into the combination; some of it joins the iron and makes it red-short.

Owing to the fortunate circumstance that Pennsylvania is blessed with an extensive deposit of pure coking coal, namely, in the Connellsville region, the demand for coke for blast furnace use was for many years satisfied by the product from that region. However, with the rapid increase in the production of pig iron the demand for good furnace coke cannot all be supplied from one source, and it becomes necessary to

draw also from other localities where the coal has the properties to make good coke, although not sufficiently pure without being put through a process of purification.

COAL WASHING IN UNITED STATES.

While the process of coal washing was firmly established in Europe during the fifties of the last century, the first attempt in this country was made only in 1869, when a small washery of about 100 tons capacity in ten (10) hours, was erected at Alpsville, on the B. & O. R. R., about 24 miles from Pittsburgh. This plant washed slack from the mines right there and the product was converted into coke at the same place. This washing plant was built by a German mining engineer named John J. Endres, who, having previously been engaged in this work while employed at Prussian Government mines, brought drawings and photographs along from Germany and put them to use as soon as he found opportunity. During the years 1871 and 1872, he built several more washing plants; in some cases in connection with so-called "Belgian Ovens," that is, retort ovens of the type now used for the utilization of the by-products from the coking process.

Such washeries and ovens were built during the two years mentioned at the Eliza Furnaces at Hazelwood, this city; at Holidaysburg, Pa.; at Irondale, O.; at Equality, Ill., and at Joliet, Ill. A mere washing plant of 100 tons capacity per ten hours was erected near Mansfield, Pa., now called Carnegie. All these establishments were planned and erected by that same engineer. Very soon after the Alpsville plant was put into operation, two companies of St. Louis, Mo., erected extensive washing and coking plants at East St. Louis, Ill. However, all the plants named have since been dismantled, chiefly because during the panic (from 1873 to 1879) there was absolutely no market for washed coke, for during that period Connellsville coke was sold at 90 cents a ton at the ovens, and that killed all competition. During 1879 there came

a very sudden revival in the iron and coke business, and at that time the price of coke rose from 90 cents to $6.00 per ton. As a consequence of this, there was for a couple of years some demand for coal washing machinery, chiefly by the furnace companies maintaining coke works for supplying their own furnaces.

During the last eight years the demand for coke has so increased that it cannot be met by the works in the Connellsville region, and so washing machines are now being erected at various places and thus the production of coke for blast furnace use is coming up to the rate of consumption.

THEORY OF THE PROCESS.

The washing process is based upon the difference in the specific gravities of the various minerals mixed with the coal as it is mined. These gravities are in the average of

Coal	1.3
Bone	1.4 to 1.8
Slate	2.3 to 2.7
Pyrites	3 to 5

If we take four pieces, one of each of these minerals, of approximately the same size and shape, put them into a long-necked bottle filled with water, then close and suddenly reverse the bottle, we shall observe that each of these bodies drops through the water at a different velocity; thus the pyrite reaches the end first, next comes the slate, then the bone and finally the coal.

It is obvious that if these same four bodies were subjected to the action of a rising current ot water they would move just in the reversed order from the former, for in this instance the coal would rise quickest, next to it the bone, then the slate, and, finally, the pyrites.

For many decades the means used for separating ore from quartz were sieves, and they were of such dimensions that they could conveniently be handled by a man. The mode of

operation was that the man put a quantity of ore into the sieve, submerged it in a vat containing water, and there jigged the material up and down while keeping it under water, until the quartz, being the lighter material, collected on top of the charge and the heavy ore settled on the screen, when he removed the quartz by scraping it off as far as it was free from ore, then put some more material into the sieve and repeated the operation until there was sufficient concentrated ore collected to make it worth while emptying the sieve entirely.

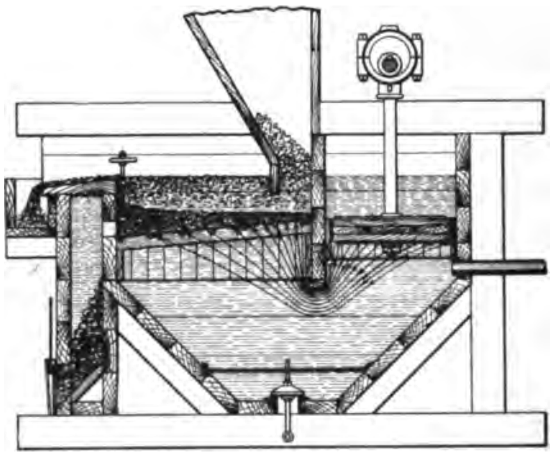


FIG. 1.

Later on, larger sieves were employed and for greater convenience suspended from counter-balanced overhead levers, or flexible rods secured to the ceiling or some upper framework in such a manner that they acted like springs, whereby the operator was relieved of the exertion of lifting the sieve and material, and had only to pull it down, whereas the alternate rising movement was caused by the springs or levers.

Still later on, the screens were hung to and operated by eccentrics mounted upon revolving shafts driven by power.

The next step was the invention of the machine known by the name "Harz Jig," shown in Fig. 1. This contrivance originated in the mining region of the Harz Mountains, in

Germany. That region is rich in minerals and has been exploited since the tenth century.

Originally the Harz Jig was used exclusively for the concentration of ores, but was later on adopted also for washing coal. This machine consists of a tank divided by a partition into two compartments. The partition reaches only a short distance down; one of these compartments contains a screen dipping towards the front of the tank. On the other side of the partition is a wooden piston operated by an eccentric.

The front plank of the screen compartment is cut down below the other sides and provided with a shelf, so that if the tank is filled with water it will eventually run out over the shelf.

The water enters the tank through a pipe in the rear, below the piston. The operation of the machine is as follows:

After the tank is filled to overflowing the supply of water is continued, and coal is admitted through the hopper at the rear of the screen; with every down stroke of the piston the water rises through the screen and lifts the coal and its impurities and makes them spread gradually over the entire area of the screen until the space above it is filled even with the overflow line. From that on, with every pound of coal that enters at the rear a corresponding quantity of washed coal is carried over the shelf by the current. This discharge of coal and water is repeated with every down stroke of the piston.

While the material travels from the rear towards the front the whole mass is lifted and dropped many times, and as with every upward movement the lighter bodies rise quicker and higher than the heavier ones, and that with every downward movement the heavier particles sink faster and lower than the lighter ones, it occurs that while a certain quantity of coal travels from the rear to the front the several kinds of material constituting the charge are being separated and ranged in horizontal layers according to their respective specific gravities. In this manner the pyrites, being the heaviest, will lie

directly upon the screen; the slate will be on top of the pyrites and the coal on top of the slate.

We see in Fig. 1 a gate attached to the inner side of the front of the screen compartment. This gate is provided for the periodical discharge of the refuse. It may have to be raised at from 5 to 15 minutes, depending on the proportion of refuse contained in the coal to be washed.

The refuse passing through this gate drops into the narrow compartment in the front below the overflow itself. This compartment holds approximately half an hour's product of refuse and is periodically emptied through another gate located at the foot of the refuse compartment.

There is also a valve in the bottom of the tank, through which any fine material that drops through the opening in the screen is from time to time discharged.

In this machine the screen is inclined from the rear toward the front; the object of this is to expedite the travel of the refuse towards the front.

It is obvious that if this machine is to perform its functions well, the operator must give close attention to the periodical opening of the refuse gate else the space over the screen may be filled almost entirely with refuse so that the latter passes over with the washed coal, which defeats the purpose of the operation. On the other hand, if that gate is opened too early and too often, coal is bound to be discharged with the refuse.

The necessity of paying close attention to the timely discharge of the refuse prevents a man from taking charge of more than, at the most, four jigs. Among the modern washeries are such that have 20 and more jigs, in which case it would be necessary to have five or more men employed to attend to the machines. For this reason means were devised for the automatic continuous discharge of the refuse, and there were several contrivances invented that fulfill this purpose with more or less perfection.

The Harz Jig experienced many modifications; some were

betterments and others not. It was supposed that by the reciprocating movements of the piston the water in the tank would perform regular oscillating motions. On the contrary, the main body of the water in the tank remains at rest and only so much is set in motion as is displaced by the piston and supplied through the pipe. This water seeks to move in the direction of least resistance, which is also the shortest way around the lower edge of the partition and through the screen; therefore, most of the water passes through the screen within about the rear half of the latter, that is, near the coal chute.

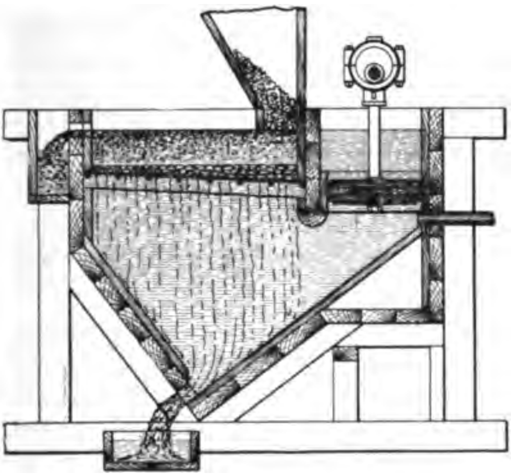


FIG. 2.

But in order that the washing operation shall be properly performed, it is necessary that the action of the water be uniform all over the screen, else the force of the current at the rear end will be too strong, so that it will not separate but only agitate; whereas at the front end it is too weak to do any work, and then there remains only a comparatively small section about the middle of the screen, over which the work is properly done. In addition to the tendency of the water to rise through the screen near the rear end, there is the further obstruction to its uniform rise, due to the greater depth of the charge at the front and the accumulation of heavy refuse there. Accordingly,

in this machine the current has its greatest force where the load is the least, and the least force where the load is greatest.

LUHRIG JIG.

Luhrig undertook to remedy the evil of the unequal action of the rising current, and reversed the inclination of the screen towards the rear, as seen in Fig. 2, so that the greatest depth and heaviest load came to be next to the piston where the current is strongest. This would have been very good, provided a slate trap had been located there, because it stands to reason that the refuse would travel towards that point; but instead of thus providing for the removal of the refuse he chose to use a bed of feldspar all over the screen, made the holes in the latter large, and let the refuse drop through those holes into the chamber below, from which it was to be removed by a continuous drain from the machine. On such machines all sizes of coal, up to above ¾" mesh, were washed. The holes in the plates which formed the screen were one-inch square and the feldspar of the size of walnuts. On account of the large holes and the exceeding coarseness of the feldspar a considerable quantity of coal goes with the refuse. At an establishment where 16 of these jigs are in operation there are three additional jigs installed that wash the refuse in order to save the coal it contains.

There is also Luhrig's jig which is intended for washing coarse coal. The jig is the same as the Harz jig; that is, its screens incline toward the front, and has slate gates there, but no feldspar is employed in it.

MODERN JIG.

Fig. 3 is a sectional view and Fig. 4 a top view of a modern jig as it is now mostly constructed. The characteristic feature of it is that the screen is narrow and long; it is never over 24 inches wide, but may be as much as six feet in length. The piston is of the same dimensions as the screen and its long side is parallel with that of the latter. This jig may be

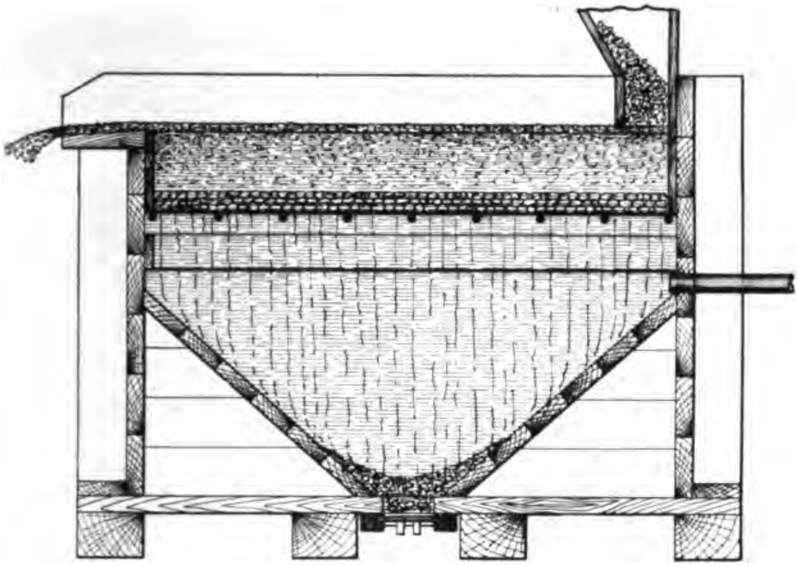


FIG. 3.

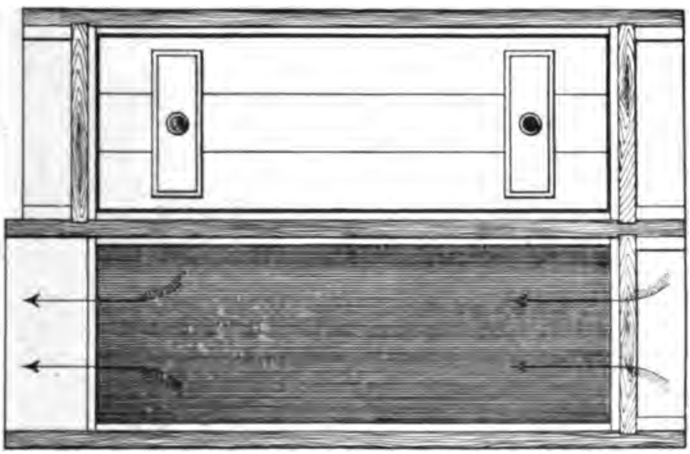


FIG. 4.

used with or without a feldspar bed. If no feldspar is used then provision is made at the overflow end of the screen for the removal of the refuse. If feldspar is used, the refuse drops through the perforations of the screen. In either case the

screen is level. The use of feldspar is advantageous chiefly in washing material from a quarter inch mesh downward, including dust; if used in washing larger sizes of coal the refuse must be washed to save the coal that dropped through the screen.

The most rational way of attaining uniform action of the current is to locate the piston directly below the screen and make it practically of same dimensions as the latter. Fig. 5 is a section and Fig. 6 a front view, and Fig. 7 a top view of such a machine. It is obvious that with this construction the screen may be of any size and shape and yet work uniformly well in all its parts as long as the piston is dimensioned in accordance with the screen.

This machine may be built with or without valves in its piston. If there is a single jig and no valves provided, the water displaced by the down stroke of the piston passes

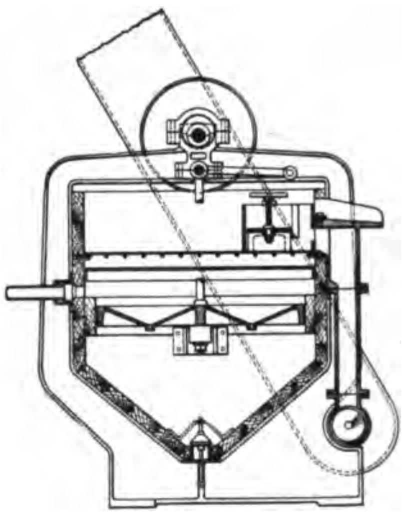


FIG. 5.

into a secondary compartment and returns again with the rise of the piston. If there are two jigs in one tank, the pistons are relatively so hung that if one rises the other descends, thus

the water displaced by the piston fills the space vacated by the other, and vice versa.

If the piston has valves, the water supply for a group of

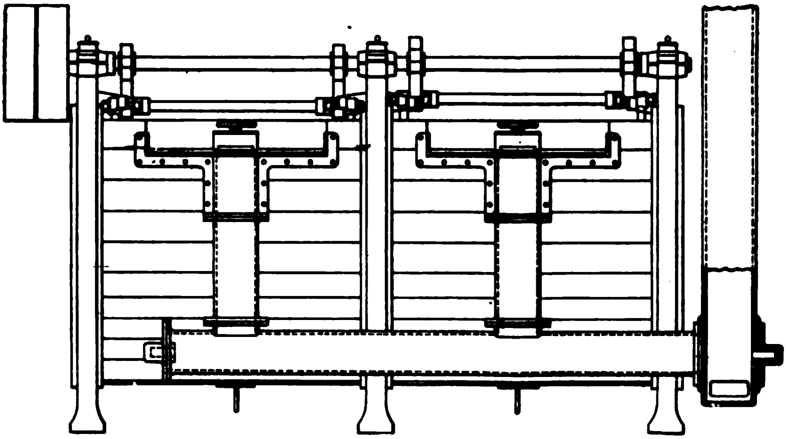


FIG. 6.

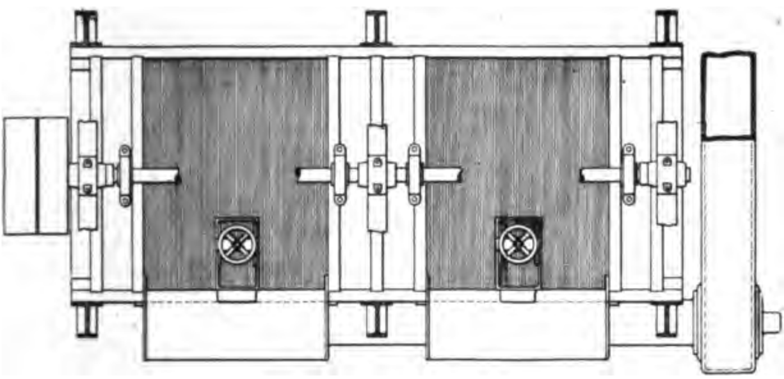


FIG. 7.

two or four jigs within one large tank, Fig. 6, is all led into a common compartment from which each jig draws its supply. If no valves are provided the water enters the space beneath the screen and above the piston.

The valves are either of steel plate or thin iron castings; in either case they are unfinished.

The periodical removal of the refuse collected in the compartment shown here at the front of the Harz jig is a drawback and is frequently obviated by the employment of a short conveying screw and a small elevator that continuously removes the refuse at the rate at which it is produced.

The continuous and automatic removal of the refuse from the screen is accomplished in several ways by the employment of certain devices. One of the oldest among them is that shown in Fig. 8. It consists of an iron pipe, usually about 3 inches in diameter, that projects upward through the jig screen about 2 inches, depending on the size and average specific gravity of the refuse. This pipe is made adjustable by means of a thread and a socket which latter is secured to the

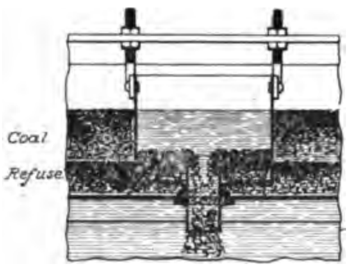


FIG. 8.

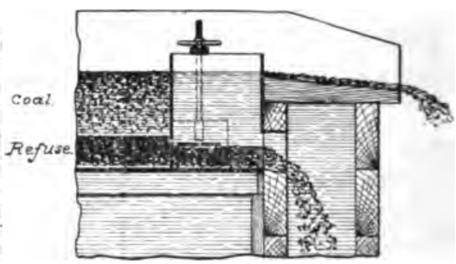


FIG. 9.

screen. The adjustment is made by screwing the pipe higher or lower according to the thickness of the course of refuse at which the device works with best results. This pipe is located in the center of the screen and is surrounded by a sheet iron cylinder, open at top and bottom, which is considerably larger in diameter and height than the pipe, and is also adjustable so that it may be raised or lowered to insure its greatest efficiency. As seen in Fig. 8, the adjustment is made by means of screws and nuts, and the cylinder is suspended from an iron bar laid across the screen compartment of the jig. By this provision the passage of the refuse between the lower edge of the cylinder and the surface of the screen is regulated in accordance with the quantity of material to be discharged through the central pipe during any given time. The refuse

drops into the space below the screen whence it is removed either periodically or continuously in one or the other manner referred to before.

With every upward current the refuse within the cylinder rises above the top edge of the pipe and as the particles toss each other laterally, a portion of that refuse enters the pipe and is thus removed from the screen. This device is very good in washing ore where the bulk of the material treated on a machine is small compared with the large quantities of coal that must go through a jig during a given time; for this reason it was not used much in the coal washing process.

Another device more adapted for coal is that shown in Fig. 9. This consists of an oblong box open at the top and bottom and provided with vertical sliding gates about 5 or 6 inches in width each. These gates are raised by the operator to the height at which the refuse will enter the space within the box as fast as it is brought upon the screen with the coal. At the opening in the front plank there is an iron baffle which causes the refuse to accumulate even with the upper edge of that baffle over which the refuse is discharged with every revolution of the eccentric shaft.

Fig. 10 shows a sectional view of a trap with two gates. Its feature is that the inner portion of the overflow shelf projects some distance into the screen compartment and is provided with an adjustable gate in length equal to the width of the jig screen. Another adjustable gate is provided at the point where the refuse drops into the refuse compartment, or to a conveying screw and elevator; this second gate performs the function of a baffle.

Every coal requires a certain height of baffle, which depends on the amount of slate and bone contained in it. With a coal containing much pyrites and little or no bone, the baffle needs to be set low, whereas with a coal containing much bone and little pyrites the baffle has to be set high. The writer knows of a case where the baffle had to be set 4¼-inch high. That particular coal is especially rich in bone and slate, but has comparatively little visible sulphur.

In all refuse traps characterized by a combination of inlet gate and baffle, both of them need be adjusted only once, until the correct height of each is found, after that they may be left untouched, no matter whether coal is brought upon the screen or not while the piston is kept moving.

All these traps are based upon the same principle which is, to sink the lower edge of the cylinder of Fig. 8, or that of the gates in Fig. 9, or that of the front gate in Fig. 10, a certain depth into the material on the screen, at which there will be just opening enough left for the refuse to enter the trap at the rate it comes on the machine with the coal. With every upward current a portion of the refuse within the trap moves into the collecting chamber, or elevator, and as in this way

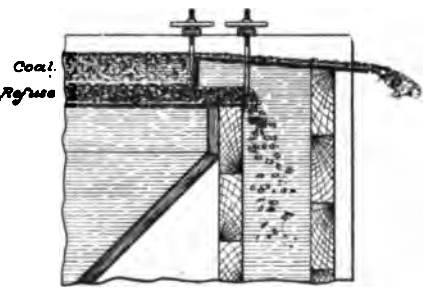


FIG. 10.

the quantity of refuse within the trap is reduced, it cannot sufficiently resist the lateral pressure exerted by the outer material, and thus while the latter sinks with the downward current there will be as large a quantity of refuse enter as has been discharged at the preceding rise of the material, etc.

BEHAVIOR OF SLATE DURING THE OPERATION OF THE JIG.

If we pick up a piece of slate and lay it carefully flatwise on top of the coal in a normally working jig, see Fig. 11, we shall see that with the first upward movement of the material the piece of slate takes a tumble, shown in Fig. 12, and with the next stroke it enters the charge edgewise, Fig. 13, and with two more strokes disappears entirely from sight. This

shows that although slate has in one way a very large area it immediately assumes a position in which it finds the least resistance, then works its way to the screen.

If a piece of slate arriving at the bottom happens to drop upon two or more pieces of slate, as shown in Fig. 14, the underlying pieces pass out from that situation with the next few strokes of the piston, and assume positions as shown in Figs. 15 and 16.

This phenomenon explains also how it happens that if a large level screen has but one outlet for refuse, at an edge or corner of the screen compartment, the refuse travels to that

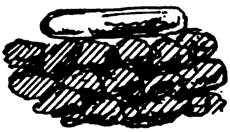


Fig. 11

Fig. 14

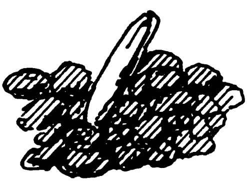


Fig. 12

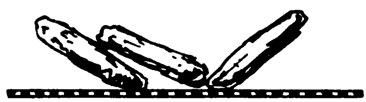


Fig. 15

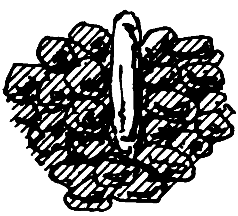


Fig. 13

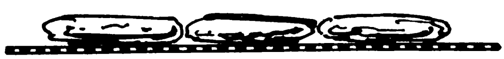


Fig. 16

outlet as if led there by a current or some other direct acting agency. This takes place by reason of the wedging tendency combined with the almost insignificant lateral resistance that a body offers when suspended in water.

Ideal results would be obtained by the washing process if all of the coal to be treated were of one size, but as this is practically unattainable we must content ourselves with the next best thing and that is to divide the material into classes by passing it over a number of graduated screens of which each retains what is larger than its perforations and thus there are as many sizes of coal produced as there are screens, plus one. This operation is practiced in well equipped washeries and is called classification.

If coal contains only slate and iron pyrites the classification needs not be carried so far as if there is bone combined with it. The specific gravities of coal and slate are in the average 1.3 to 2.3 respectively, but bone is only slightly heavier than the coal, in the average about 1.60, therefore, if there is so much of this material mixed with the coal that it would increase the ashes in the coke from such coal to a detrimental percentage, it becomes necessary to make the classes so many that most of the bone will be ejected by the washing process. On the other hand, if the proportion of bone is not so large as to seriously impair the value of the coke for blast furnace use, the classification needs not be carried so far as when the other condition prevails.

CALCULATION OF MESHES IN SCREENS.

If two bodies of different specific gravities are exposed to the action of a rising current, and those bodies are not of the same size, it may occur that the specifically heavier body will be lifted just as high and as fast as the lighter one.

To illustrate this, let us assume that we have a piece of coal of the specific gravity 1.3; and a piece of slate of the specific gravity 2.3. Let us see what must be the respective dimensions of these bodies in order that they will both be lifted by the same current or dropped in still water with equal velocities.

Since gravity is the force that resists the effect of the current in its tendency to lift the bodies, we know that its effect is the greater the more matter a body contains. This again is

a function of volume and density. Consequently, the larger and denser a body is the heavier it is, too; hence the resistance a body offers to being lifted is the product of volume by density or specific gravity, and we may therefore say the tendency to sink or to resist lifting is

$$\textit{volume} \times \textit{spec. gravity} = vs.$$

On the other hand, it is obvious that the effect of the lifting current, respectively the resistance a body meets with when it drops through a liquid or gas, is in proportion to the area that body exposes against that medium. Hence, if volume and specific gravity stand for the resistance to being lifted, the area of the body favors that lifting, for the greater that area the greater contact has the current and the greater its effect. Hence we get the relation

$$\frac{v\,s}{a}$$

in which a is the arèa exposed to the current.

Now, if we have two bodies of different specific gravities and wish to know of what relative dimensions they must be in order to rise or sink with equal speeds, we get the equation

$$\frac{v\,s}{a} = \frac{v_1\,s_1}{a_1}$$

Owing to the buoyancy of submerged bodies we cannot put in the equation the specific gravity as if weighed in the air, but must deduct from it the weight of the water each of those bodies displaces and so we get for s and s_1: $(s-1)$ and (s_1-1) and now the equation is

$$\frac{v\,(s-1)}{a} = \frac{v_1(s_1-1)}{a_1}$$

and since for volume we may substitute d^3 and for area d^2, the equation is transformed to

$$\frac{d^3(s-1)}{d^2} = \frac{d^3{}_1(s-1)}{d^2{}_1}.$$

and further, by canceling,

$$d\ (s-1) \quad = \quad d_1\ (s_1-1)$$

If now we substitute definite values for d, s and s, as, for instance, 1", 1.3 and 2.3, we get

$$1(1.3-1) = d_1(2.3-1) = 1\times0.3 \doteq 1.2d_1$$

and finally

$$d_1 = \frac{0.3}{1.3} = 0.23$$

That means that if when washing coal on a jig there are pieces of coal of the size of a one-inch cube, the current that lifts such a piece of coal lifts also a cube of slate the sides of which are 0.23 inches; and as a matter of course, also all slate smaller than a cube of 0.23 inches.

Supposing the coal contains much bone of the specific gravity of 1.75 and we wish to know what range of sizes may be brought upon one and the same jig so that the bone will go with the refuse, we have the same equation as above

$$d\ (1.3-1) = d_1(1.75-1)$$

$$d_1 = \frac{0.3}{0.75} = 0.4\,d$$

that is, the current that lifts a piece of coal of the size $=d$ lifts also a piece of bone of the size $0.4d$.

Consequently, in determining the meshes of a series of screens, the difference between two succeeding sizes of meshes must not be as large as from 1 down to 0.4, but only from 1 to say 0.5.

Hence if the meshes in one section of the screen are 1-inch square, those of the next following section must not be

smaller than ½ an inch, else all bone from 0.4 downward will pass with the coal instead of with the slate.

The relation once established holds good for all classes that may be produced by the screen provided the specific gravities are constant.

Bone is chiefly earthy matter impregnated with bitumen. It is not always of the same specific gravity but varies according to which of the constituents predominates—whether rock or bitumen. Therefore in a case where much bone occurs in the coal the approximate average specific gravity of the bone must be ascertained and then only can the number of classes and jigs be determined to advantage.

CAPACITY OF COAL WASHING MACHINES.

A well working jig will wash about four tons of coal per square foot of jig screen in 10 hours; this is of Pittsburgh coal.

If a coal contains much bone the process is much slower than with coal free from bone.

The finer the coal must be crushed in order to separate the impurities from the coal preparatory to washing, the longer it takes to wash it.

An advantage is to crush all coal to a certain maximum size, as, for example, to pass through a ½-inch, ⅝-inch, or ¾-inch square mesh.

If there is no provision made for washing the fine coal, from ¼-inch mesh down, on separate machines, it may be washed together with ½-inch or even larger coal, but only on a level screen, as otherwise a great portion of the fine coal is sucked through the screen whenever the current passes backward. With slanting jig screens the highest part of the screen is during much of the time exposed, that is, not covered by a bed of refuse as in the case of a level screen. To save the fine coal that drops through the screen is not commendable for the reason that there is also a large quantity of sulphur and fine slate mixed with the coal below the jig screen. Therefore, such coal would impair the purity of the coke if saved.

The first washeries built in this country were very simple compared with the large modern plants as established at some of the coke works in Westmoreland county, this State, and also elsewhere. A feature that adds very much to the cost and complication of such plants is the provision made for collecting and saving of the sludge. Another feature is the present tendency to locate heavy machinery in the third or fourth story of a wooden building.

Things can be very much simplified by washing the fine coal separate from the coarser coal, and passing it over slanting draining screens, directly as it leaves the jigs. This would do away with the expensive and trouble-breeding sludge basins. The water could be used over after it passed through a comparatively small settling tank provided with means for the continuous removal of the sediment.

In this case the coarse coal could be conducted directly into the elevator booth, and the water would flow back to the centrifugal circulating pumps, to be used over again.

The quantity of water used in washing coal is, if none is wasted, approximately 1½ gallons per minute for every ton of coal washed in 10 hours. In this the water is not used over. Where water is scarce and it must be used repeatedly, the continuous supply required is from 10 to 20 per cent of the above amount.

Water for washing coal should be renewed as often as conditions permit for there is always more or less sulphur and fine refuse suspended in it which is bound to have some effect upon the quality of the product of the washery.

As to the cost of construction of coal washery plants, there is necessarily a great variety of conditions contingent to different localities, which have their influence upon the cost. However, as an approximation, a plant will cost from $35 to $50 for every ton of its washing capacity in ten hours. Thus a plan washing 500 tons in 10 hours at probably $45 per ton, will cost $22,500.

Description of Washing Plants in Operation.

BY W. G. WILKINS,*
Past President.

Mr. Diescher has read a very interesting paper devoted mainly to a history and description of the development of the "jig" washer, from the "Harz" washer down to the machine, as now in use in this country, and has very clearly explained the principles of its operation. It occurred to the writer, as supplementing Mr. Diescher's paper, that descriptions of a couple of complete washing plants, including not only the washing machines themselves, but also the breaking, crushing and coal handling plants might prove interesting to the members, and he, therefore, gives below two descriptions of plants with which he has had some connection; one a plant using the "jig" washer and the other a plant having a very different type of washer, which is a modification of the "Campbell" washer, a washer well known and long used in metal mining.

The writer in 1899 made an examination of a comparatively small and simple washing plant in Indiana County, Pa., where the coal mined and coked was the Upper Freeport, the coke plant consisting of 130 ovens, 12 feet diameter and 7 feet in height.

The original washer was burned down in May, 1898, and rebuilt on improved lines, being completed in October of the same year.

The washing plant consisted of the crushing rolls, one for fine and the other for coarse coal, a shaking screen, revolving screen; six three-compartment "Stein" jigs, three for fine and three for coarse coal, and a re-washing jig with elevators, centrifugal pump, settling and storage bins. The whole plant was substantially constructed and housed in frame buildings which were sided first with hemlock boards, then a layer of

* Of W. G. Wilkins Co., Engineers and Architects, Pittsbbutgh, Pa.

building paper, outside of which were surfaced siding boards. The machinery is operated by a 125 H.P. plain slide valve engine, the steam for which is furnished by two 75 H.P. cylinder boilers.

OPERATION OF WASHING.

The coal is dumped from the tipple to the raw coal bin, from which it is carried by an elevator and discharged into a chute leading to the coarse coal crusher. This chute has a screen at the upper end just over a shaking screen, through which all coal smaller than 1½ inches falls, all the fine coal going through the shaking screen to the fine coal bin beneath; the 1½-inch going to the fine crusher and then to fine coal bin. The coarse coal in trough goes through coarse crusher and then elevated back to shaking screen, the fine coal going to fine coal bin and balance to fine crusher and then to fine bin.

From the fine coal bin the coal is hoisted by an elevator to a revolving separating screen; the larger sizes going to the three coarse jigs and the smaller sizes to the three fine jigs. The washed coal is carried by system of troughs or gutters to the washed coal boot, and the refuse to a rewashing jig from which the fine coal goes to washed coal boot and the impurities to the slate boot.

From the washed coal boot the coal is elevated by an elevator, having perforated buckets to a conveyor which takes it to a drying bin where it is left 24 hours to drain the water from it. After this it is taken by conveyors and elevator to the larry charging bin which holds 90 tons of washed coal. The water from washed coal bin goes to a settling tank, and the sludge or very fine coal is taken by a screw conveyor to an elevator which takes it to a compartment in the charging bin.

The refuse from the re-washing jig goes to the slate boot and is discharged into a trough through which runs the water from the mine which carries it to the creek.

The water is circulated by two centrifugal pumps and all

the water required to be replaced is that carried to the bins with the washed coal.

The capacity of the plant is 400 tons in eight hours, but it could safely be run up to 600 tons in ten hours, if necessary.

From the above description one might be led to think that it was a very complex process, while the reverse is the case, as the work is almost automatic and requires but little attention, only two men being employed in the washer house proper and one man outside in the building containing the drying bin.

COST OF WASHING.

The following gives the cost of labor used in operating the washer:

One-half fireman's wages	$ .88
2 men in washer house	3.50
1 man in dry bin house	1.40
Total	$ 5.78

For an output of 200 tons of coke daily, this would be 2 9-10 cents per ton of coke, or on a basis of 135 tons, the average daily output of October and November, 4 3-10 cents per ton.

During the first four months of 1898, with the old washing plant in operation, the percentage of yield of coke from the coal was 53%, and the tons of coke per oven was $3\frac{3}{10}$.

During the first four months of 1899, the new plant showed the following results: Percentage of coke from coal, 49%; tons of coke drawn per oven, $3\frac{1}{10}$. The plant as run up to October did not receive the sludge in the water from the washed coal bin, but after this was done the results were: Percentage of coke from coal, $57\frac{8}{10}$% and coke per oven, $3\frac{4}{10}$ tons. These last results showed an increase over the first four months of 1899 of $11\frac{8}{10}$% in yield of coke from the coal and an increase in coke per oven of nearly 10%.

The following table shows a comparison of the coke made from unwashed and washed coal:

INDIANA COUNTY COKE.

	Unwashed Coal.	Washed Coal.
Ash	13.68%	8.63%
Sulphur	1.69	0.87
Phosphorous	0.28	0.115

The writer does not have at hand the analysis of the coal before washing, but to the best of his recollections it ran about .2% in sulphur.

CASCADE COAL & COKE COMPANY WASHING PLANT.

A very successful coal washing plant is that of the Cascade Coal & Coke Company at their mine at Tyler, Clearfield County, Pa. The coal mined and coked is the Middle Kittanning, is about three feet thick, and contains an average of $2\frac{8}{10}$% of sulphur.

The washing plant was installed by Heyl & Patterson, Inc., in 1905, and at that time there was in operation 200 coke ovens requiring 600 tons of coal, but the intention was to increase the number of ovens to 400, requiring 1,200 tons daily. For this reason, the first contract for the washing plant guaranteed a capacity of 75 tons per hour or 600 tons in eight hours, and provided that there would be no changes required when the size of the plant was doubled, except that when the extension was made, the crushed coal belt conveyor would have to be lengthened to extend over and feed the additional washers, and the belt conveyor on which the traveling elevator deposited the washed coal in the bin house would also have to be lengthened.

The coal breaking plant which was to crush the coal for the washing plant had already been contracted for and was under construction when the first contract for the washing plant was executed. The contract for the breaker plant guar-

anteed a capacity of 75 tons per hour, and specified that the only change necessary when the plant was increased to 150 tons per hour was to increase the speed of the belt conveyor from 300 to 500 feet per minute.

The following is a brief description of the breaker plant, taken largely from the contractor's specifications:

The trips of pit cars are fed by a trip feeder to a "Phillips" cross-over dump, where the coal is dumped into a bin. The

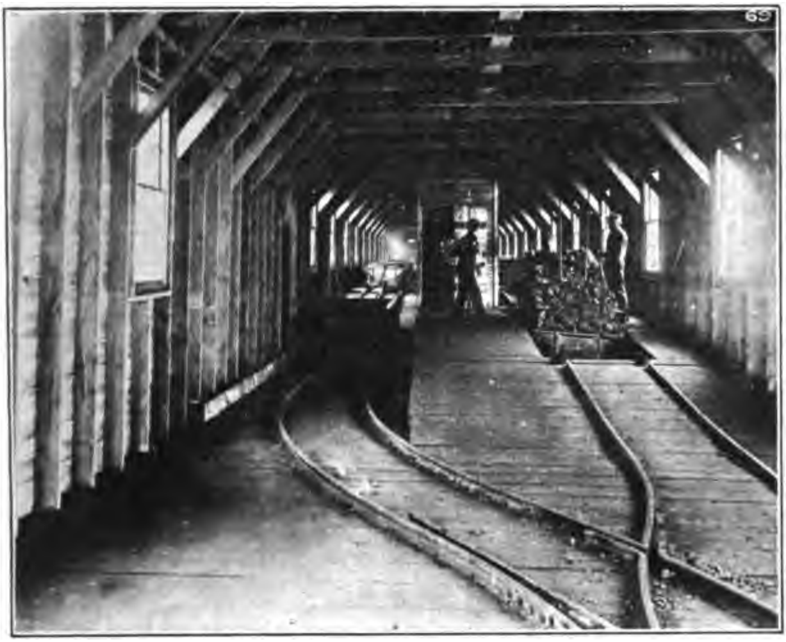


FIG. 1. Interior of Tipple House: Loaded coal being dumped and empty cars going back.

empty cars are returned from a "kick-back" to a "trip-maker" which pushes the empty cars back one car length at a time on the trestle approach to the tipple. (See Figure 1.)

By means of a feeder the coal is drawn from the bin and discharged into a screen chute, the bottom of which is perforated.

The fine coal passing through the perforations is passed by a system of chutes to the elevator boot; the coal which passes over the screen is discharged by a chute into a "Bradford" patent breaker, the breaker refuse being dumped into railroad cars, or to a conveyor which takes it to the boiler house. The refuse contains about 50% coal and is the only fuel used under the boilers.

FIG. 2. Top of Crushed Coal Bin, showing belt conveyor and tripper.

The breaker is provided with a screen jacket, beginning at the receiving end and extends two-thirds of its length. The coal passing through the screen jacket drops into a compartment of a hopper under the conveyor, under the breaker, and thus is passed by chutes to the elevator boot; the coal passing over the screen jacket drops into the other compartment of the breaker hopper, and then by a chute and feed roll to a

crusher, from which the coal is passed by a chute to an elevator.

From the head of the elevator the coal is discharged through a chute into a belt conveyor which runs over a storage bin above the washer. (See Figure 2.) The bin is of wood construction, having a capacity of 150 tons, the sides

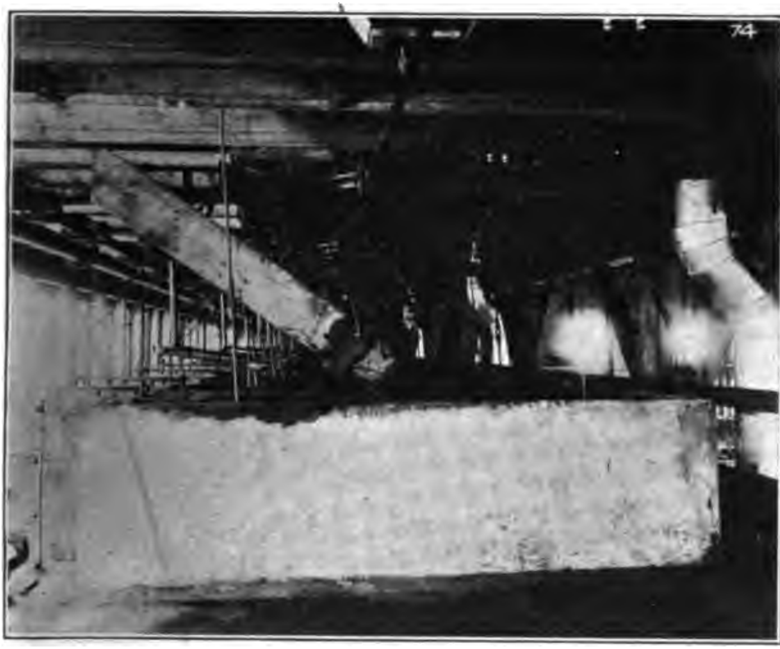


FIG. 3. View of Washers, showing chutes for feeding crushed coal to washers.

and bottom being made of two layers of 1½-inch oak. Suitable openings are provided in the bottom of the bin for supplying the mechanical screw feeders which deliver the coal to the chutes leading to the washery. While passing down these chutes the coal is mixed with a spray of water from pipes which form part of the piping system from the tank. (See Figure 3.)

The water supply for the washers is taken from a well in

the basement of the washery building, and is elevated by means of a pump to a tank located in the third story. This tank has three lines of pipe; the supply, the overflow, which leads back to the well, or by means of a bleeder discharges water outside of the building at ground level, and the washer supply pipe.

FIG. 4. View of Washers, showing bumpers and cars.

The washers are the standard "Campbell" washers, there being 18 installed under each contract, or total of 36, there being in the complete plant two groups of eight and two groups of ten, each group being driven by two 7x7-inch vertical steam engines, through one belt and one spur gear reduction. These washers are simply shallow boxes open at the ends; the bottom of bed built of white oak, having riffles covered with No. 20 galvanized iron. They are hung so that

by a steel cam and rocker mechanism they are moved back and forward lengthwise, the fine washed coal being carried off the front end by the water, and the refuse carried off the rear end, by the back end of the washer striking a bumper on the backward movement of the stroke. (See Figure 4.) The capacity of a single washer is five tons of crushed coal per hour at this point, as shown by the tests given later.

From the washers the coal is sluiced by means of stationary and swiveling sluice boxes to the storage pit which is divided into three compartments, each having a capacity of 210 tons. The refuse from the washer is sluiced by means of stationary sluices to the refuse pit which is divided into two compartments, each having a capacity of 80 tons. The water from the washed coal filters through the coal into a system of drain trenches, and returns by gravity to the well from which is taken the supply for the entire plant.

A very interesting feature of the plant is the traveling elevator for taking the coal and refuse from the drainage pits and putting it on to the belt conveyor which takes the coal from the washer building. (See Figure 5.) The principal parts of this traveling elevator are a bridge traveling longitudinally over the coal pits, having a steel trolley which travels lengthwise on the bridge, and carrying a vertical elevator leg, which can be raised or lowered in the coal pits. The bridge consists of two steel girders, each end being supported by cross girders, forming the trucks. The trucks have each two 27-inch wheels on $3\frac{1}{8}$-inch axles in brass lined cast iron journals. The trucks travel on tracks each side of the pits, formed of 90-pound tee rails, bolted to the top of the concrete sides of the pits. The power for moving the bridge is furnished by a 15 H.P. motor and is transmitted to a line shaft by cut gears, then by cast steel gears to the truck axles, one wheel on each truck being driven, the wheels being double flanged.

The trolley frame is of structural steel construction, rigidly braced and stiffened, and is mounted on four 16-inch diameter double-flanged steel wheels, running on 70-pound steel

rails on the bridge girders. Power for moving the trolley along the bridge is furnished by a 15 H.P. motor and is transmitted to the axles of the trolley wheels through suitable gearing.

The elevator leg is of one section, rigidly constructed, the web being formed of a wooden truss, with steel guide

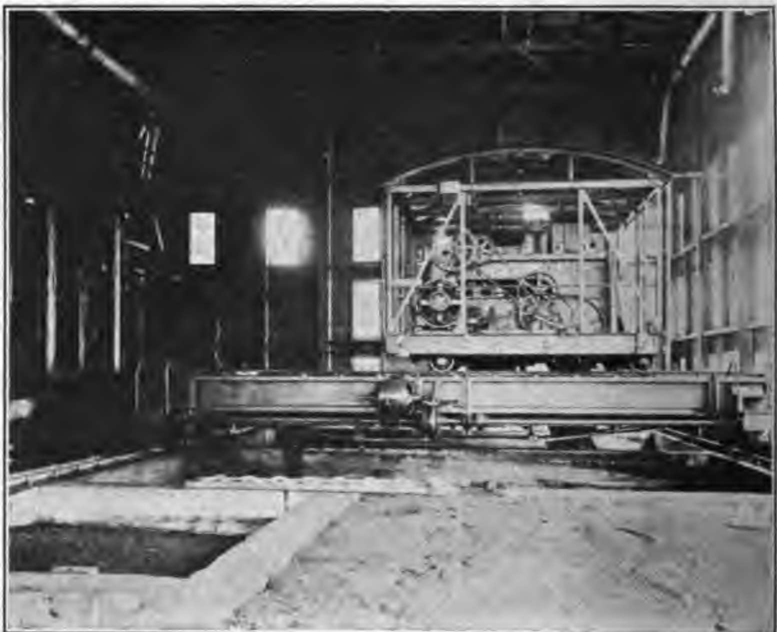


FIG. 5. Washed Coal Elevator.

channels on each side of the leg. The leg is raised and lowered by means of steel cables and winding drums, the power to drive these being taken from the motor which drives the elevator. The elevator consists of two strands of steel thimble roller chains with special attachments and 26x15x12-inch brackets, spaced 18-inch centers. The power for operating the elevator is furnished by a 20 H.P. motor. The elevator discharges onto a belt conveyor, which in turn discharges

onto another belt conveyor, running parallel with the pits, and this belt delivers the coal to the belt in the tipple house leading to the larry bin. (See Figure 6.) The belts are all 24-inch four-ply rubber, with ⅛-inch rubber coating on the carrying side.

The refuse is discharged through a hopper and chutes into a belt conveyor, which discharges into a hinged chute leading to the railroad cars which are hauled away by the railroad and used for ballast and filling.

FIG. 6. View showing belt taking washed coal to larry bins.

I might say that this elevator was the first of this design ever built, and it has been very successful.

The contract for the first installation specified that there would be no increase in the size of the following parts when the plant was doubled, viz.: Crusher, elevator, driving ma-

chinery for belt conveyor, except motor. The traveling elevator was guaranteed to be of sufficient capacity for the increased size of the plant.

The contractor guaranteed that the total waste, including the breaker waste, would not exceed 15% when furnishing coal for coking purposes, and that in 72 hour coke the sulphur should not exceed 1%.

The result of the first installation was so satisfactory that in October, 1905, another contract was made for the extension of the plant to double its capacity, and the extension was completed in February, 1906.

On completion of the extension, a three-day test was made of the original installation, and also a ten-day test of the additional plant, to determine whether the guarantee as to capacity, amount of refuse, and quantity of coke had been filled. The tests began February 27th, and were completed March 10th, the duration of each day's test being from one and one-half hours to five hours and fifty minutes, the average length of the ten tests, viz.: Four hours for the new plant and two and one-half hours for the original plant.

The result of the capacity and refuse tests are here given:

	Original Plant.	New Plant.
Raw coal washed, per hour ...	89.0	89.8
Breaker waste	6.24%	6.24%
Washer waste	9.12%	7.86%
Total waste	15.36%	14.10%
Average waste (both plants)..	14.73%	14.73%
Percentage of sulphur, 72 hr. coke, (H. & P. chemists)....	1.085	1.071
Percentage of sulphur, 72 hr. coke, (Coke Co. chemists)...	.986	.993
Average of sulphur, 72 hr. coke.	1.035	1.032

These results being so close to the guarantee of the contractor, the Coal Company decided that although the sulphur was a trifle over 1%, they would accept the plant.

The entire plant has been in operation over two years,

and on March 22nd, 1907, an average analysis of 32 cars of coke showed that after two years' operation the plant has not deteriorated so far as the quality of the coke is concerned.

The washer and storage building (see Figure 7), 74 feet 6 inches by 182 feet in length, is a wooden frame building, the main posts being 12x12 inches, and the sides instead of being covered with wooden siding or corrugated iron, are formed

FIG. 7. View of Washer Building and Power House.

of curtain walls, of a single thickness of brick, built in between the posts, forming a much warmer building. The height of the building is 59 feet from top of foundations to ridge of roof. The supports of the washing machinery are entirely independent of and not connected with the frame work of the building, so that no vibration is transmitted to the building.

The building is heated by what is known as the fan system, and is proportioned to maintain a temperature of 50 degrees Fahr. inside, when the outside temperature is 10 degrees below zero. The cold air is blown through a box containing steam pipes and the heated air distributed through the building to various points through galvanized pipes ranging in size from 46 inches diameter to 8 inches diameter.

The photographs of the work were kindly furnished by Mr. J. L. Robb, Chief Engineer of Heyl & Patterson, Inc.

Wm. E. Winn: Mr. Wilkins in his description of the Tyler Washing Plant has only briefly described the washing machines and has only touched on their operations, and I desire to supplement his description with an explanation of the principle and operation of this type of washer, as it is different from the jig type described in Mr. Diescher's paper.

The washer utilizes two of Nature's forces, namely, those of gravity and momentum, and it is intended that a harmonious combination of the forces of gravity and momentum should be effected, the principle is not alone that of time intervals required for various particles to fall through a given space in water.

The ordinary Miner's gold washing pan in the hands of an expert manipulator has never been excelled in saving mineral, no matter how minute. One element is to copy, not only the form and principle embodied in the gold pan, but also its movements.

When the washer is in operation with its bulk of coal and water, the reciprocating movement of the table, together with the percussion and time intervals required for various particles to fall through a given space in water, induces the separation of the valuable and impurities into two principle layers; the top strata or valuable is discharged at the lower end of table by floatation, the lower strata or impurities is conveyed from the table by the percussion; the large dense stuff at the upper end of table, and the substratum of minute

sulphuric and slaty matter through the intervening space between the riffles, having double inclined faces. The number of riffles and pockets extending the length of the table will be as many miniature operations; each pocket on a different grade of material. The capacity of the washer is so regulated that the pockets will be kept about full; but there will be a graduation of average densities from the head of the

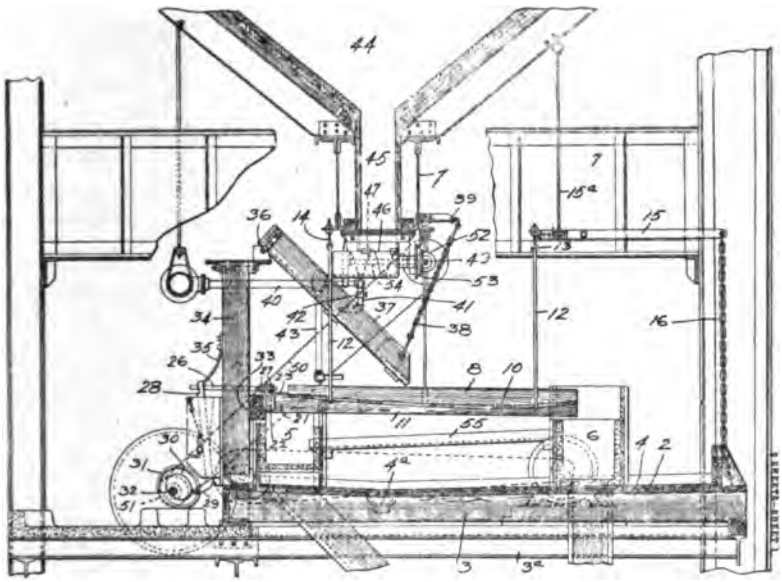


FIG. 8. Cross section Heyl & Patterson Coal Washer.

table where it is most dense, to the tail end of the table, where it is least dense. The pockets near the head of the table readily hold the large impurities of first grade density, the intermediate pockets (that is those at or near the middle of the table) hold the fine stuff of second grade density, while the pockets at or near the tail end of table holds fine stuff of third grade density, or generally a sulphurous coal. The materials of different grades of density finds lodgment at points along the series of pockets, as the conditions favor.

The pockets in succession may be considered as so many miniature jigs, that are "bedded" and fed most favorably with the "classified material," as the pockets are kept about full of fine stuff, the travel of the large and first grade of impurities is over the riffles towards the head, being conveyed by the bumping action, and the coal travels above the riffles towards the tail, being conveyed by floatation.

The reciprocating motion of the table keeps the materials over the riffles thoroughly agitated, and the bumping action causes the bed of material to turn over and over in the water, so that a thorough separation takes place. The constant agitation of the entire mass works to the surface of the water the coal, which floats away to the tail end of the table.

In the operation of the table the higher grades of density crowd out the lower grades of density, like densities clinging together.

The movement of the table is accomplished by means of an eccentric cam-lever and connecting rod. (See Fig. 8). The object is to provide for a slow forward movement, ending smoothly, and a more rapid backward swing, ending with a jar. This movement is accomplished by the shape of the eccentric and the arrangement of the suspended connecting lever and rod.

It should be understood that floatation, or suspension, or partial suspension of the particles constituting the coal, in the water, is the condition to be closely observed; and the amount of agitation should be adjusted so that the coal particles, by reason of partial floatation, will be principally affected by the water flow, while the heavier impurities, which remain in contact with the table, will be principally affected by its longitudinal, to and fro, differential vibration and bumping action.

DISCUSSION.

The President: We have heard from Mr. Diescher and from Mr. Wilkins and the paper is now open for discussion. The subject is one of considerable importance at this time. It

appeals to me especially on account of a statement I noticed recently that the Connellsville coke ovens were going out at the rate of a thousand a year. This was quite a surprise to me, as I had no idea that the coals were being exhausted so rapidly in this district.

Mr. Wilkins: Have you ever heard of any coal that would make first-class coke in a bee hive oven that would not make good coke in the by-product oven?

Mr. Diescher: I never heard of such a case. In Germany, for instance, they have no others than by-product ovens. I know that one and the same coal coked in a by-product oven makes a denser and, therefore, specifically heavier coke than if coked in a bee hive oven.

In 1871 a number of by-product ovens were erected at the Eliza Furnace, this city, and later on in the course of several years, their number was at least quadrupled, and for a considerable time those furnaces used chiefly the coke from by-product ovens. I remember well that in a conversation I had with the superintendent of the furnace at that time, he said that their own make of coke is much denser than that from bee hive ovens, and, therefore, required a stronger blast. But this objection was generally brought against coke from retort ovens which, then, were called "Belgian" ovens.

The coals mined at Johnstown and Holidaysburg, Pa., Joliet and Equality, Illinois, would not coke at all in a bee hive oven, because they lacked the necessary percentage of volatile combustible matter which furnishes the heat in the coking process. With retort ovens all, or at least sufficient gas is converted into heat to carry out the process, but in bee hive ovens a very large proportion of it is wasted.

Mr. Wilkins: I don't think you understand the point I tried to make. On the part of most of the builders of by-product ovens their claim is that they can make a coke out of a coal that would not make coke at all in a bee hive oven. This is just the reverse: coal that would make first-class coke in a bee hive oven and yet would make soft, spongy coke in a by-

product, just the opposite of what the by-product people generally claim.

Mr. Diescher: As far as I know any coal that cokes in a beehive oven will coke also in a retort oven. Coke gets spongy if there is not enough heat produced to perform the process, but also if there is too much heat, owing to which latter circumstance the gas is developed too fast.

A by-product oven may be too hot for a very rich gas coal. In beehive ovens from 12 to 14 barrels of water are poured over the coke, and thus the oven gets very much cooled down. I remember that at the Eliza Furnace they too poured water into the retort ovens, not such quantities though as in beehives, but yet enough to cool the ovens down, because they were too hot for immediate refilling. The coke got what is called black feet. It is very likely that the ovens you have in mind were very hot, too, and perhaps much too hot for so rich a gas coal as that of the Connellsville region.

A. Stucki: I would like to ask a question, and I would like to be corrected if I am wrong. If I understand matters aright the device described by Mr. Wilkins is on an entirely different principle from this device before us. Mr. Diescher's device is based on a piston washer, agitating the water by a piston, while in Mr. Wilkins' device I understand the water flows over a vibrating table which strikes a bumper.

Now what I would like to know is in the first place which is the best principle, the best device; and secondly just a little of the history of the device Mr. Wilkins has described, whether this is the first device or whether it was extensively in use.

Mr. Wilkins: It was in use for metal mining for years, but it is only in comparatively recent times that it has been used for coal washing. As to which is the best practice, that is pretty hard to tell. One coal might give good results with one type of washer and poor with another, and vice versa. I would not advise anybody to make a contract for a washing plant for any particular coal until thorough and exhaustive ex-

periments had been made with a particular washer for a long enough time to tell what that washer would do with that particular coal.

Mr. Diescher: The device referred to is the so-called "bumping table" and was invented many years ago by Prof. Rittinger, of the Austrian Mining School, at Leoben. In his well-known book, on the concentration of ores and coal, published in the sixties of last century, he mentions that the "bumping table" has also been tried to wash coal on, but its operation is too expensive because too slow. Furthermore, it requires special preparation of the material to be treated. For the process on the "bumping table" the material has to be *classified* by a current of water whose velocity gradually decreases by allowing it to spread over successively larger areas whereby its energy is decreased also. If fine coal is carried by such a current the heaviest particles precipitate first, then the next heaviest, etc., to the end, where even the lightest settle. If provisions are made to collect the several grades of sediment in a sufficient number of compartments, by baffles, etc., each grade is put upon another "bumping table," whose oscilations and the sheet of water are commensurate with the size of material to be treated on that table.

The washing or *separation* of the different constituents is accomplished in the way that a thin sheet of water is led over the table and as the specifically lighter particles of the material are larger than the heavier ones, they project higher from the surface of the table and thus expose a larger area to the action of the water than the finer grains; moreover, the water in immediate contact with the table is retarded in its velocity and weakened in its carrying capacity by its friction upon the table, so that even a perfectly smooth table as, for example, one covered with a slab of slate, or sheet rubber, without any riffles, will answer the purpose, and in fact, the first tables used for ore were smooth. The material to be treated is fed upon the table in the condition of a very thin sludge.

Walter Koch: Have you ever tried a dry separator with coal?

Mr. Diescher: I have never tried it, but I am aware that it has been done. Dry separation has also been tried by mere screening, but with little success.

Mr. Koch: With a good dry separator you can take the flue dust from a copper furnace or a lead furnace, you can take all the values out. After you get the lead out of the flue dust you can take the metal and float it on water in a bucket; and after stirring it as hard as you like there will still be three-fourths of it floating; showing that no wet separator can possibly separate it. It is like a Wilfley table. Instead of water there is an air current underneath and there is a pulsating movement. I was a skeptic on dry separators a year ago, but this one has turned $300,000 into the pockets of friends last year.

Talking about coke from washed coal, I can tell you something about using such coke. I bought a lot of coke one time from a new coal property, and it worked first rate in a copper furnace. It worked first rate with hot blast and pretty well with cold blast. I then got some more from the same people and it did not work well at all. I investigated and found that they had been selling their coke so fast that they had stopped their washers. The result was that it did not pay me to get that coke. It did not pay me to freight 22% of ash. The ash went up from 11% to 22% and I finally had to abandon it.

A. E. Anderson: Will gas coal and steam coal coke as well as Connellsville coal after washing?

Mr. Diescher: Cannel coal is rich in gas, but poor in carbon and, therefore, it yields no coke.

Before the Mechanical Section, April 2, 1907.
CHAIRMAN SUMNER B. ELY, PRESIDING.

Mining Coal.

BY LEE C. MOORE.*
Member.

The consideration of the subject of mining coal is an interesting one at all times and it is thought possible to make it more so by placing before the Society and its friends some of the details of the operation of the largest company in the Pittsburgh District, producing more than 17,000,000 tons of coal per annum.

There is a superintendent, in charge of one to three mines, depending upon their size and convenient location. Each superintendent has an office at some central point within his district, with the necessary force of clerks for time and pay roll work. This office is connected by private telephone system with the central office in Pittsburgh, from which, in a general way, all operations are directed. There is in direct charge at each mine a mine foreman, who has a certificate of competency from the State and is responsible for the mining and underground work. Next to the mine foreman come the fire bosses, from one to three, depending upon the size of a mine. These fire bosses, also, have certificates of competency from the State, and it is their duty to examine the mine within three hours before the miners go to work, to see that all working places are free from gas and are otherwise in safe condition.

The mines are developed on the lines of projected plans and all work driven to a line of sights or points put up by the engineers. All workings are measured up quarterly by the engineers, plotted on the mine maps and sun prints of copies of such maps furnished to the superintendent and mine foreman.

The mining or undercutting of the coal is done mostly

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with machines, the depth of the undercut being from 5 to 7 feet, depending upon the height of the vein. The undercut should be as deep as the face of the coal is high from top to bottom. The man running the machine is called the cutter, and he has with him a scraper, or helper, who removes the slack from the cut and assists in moving the machine. The machines in use are principally of the electric driven chain type. There are, also, in use still, some air driven machines of the punching type, but not so many as formerly, as the cutters prefer the electric machine; because with it the man operating it can stand by and watch the machine do the work, while with the punching machine it is necessary that the operator direct it, and, in doing so, he, of course, receives more or less of the shock from the machine. After the coal is undercut the loader takes charge, drills and shoots the coal down and loads it into the mine cars. The loader, also does the posting and sees, when the coal is loaded out, that the room is left in safe condition for the machine runner to work in.

The coal is gathered from the face of the workings with mules to a central point (known in mine parlance as a parting) from which it is delivered to the tipple on the outside by some form of mechanical haulage—either wire tail rope, wire endless rope, electric locomotive or air locomotive, dependent on the grades and conditions of the mine. The track in the rooms is made of 3x4 wooden rails. From the mouth of the room to the parting the track is made generally of 16-pound T rail, and from there on to the tipple the roads are laid with from 30 to 60-pound T rail. The electric locomotives used in hauling run from 10 to 20 tons; ordinarily, the 10-ton locomotive is equipped with two 40 horse-power motors, the 13-ton with two 60 horse-power motors, and the 20-ton with three 60 horse-power motors, the latter being a six-wheeler. These locomotives haul on grades varying from 0 to 2½ per cent, and will haul a train of 70 wagons; the average weight of each wagon being about 5500 pounds.

After the coal is delivered at the tipple it is there dumped

on the screens and is separated into three sizes, as it falls into the cars, on which it is shipped. That going over the 1¼ inch screen is called lump; that passing through the 1¼ inch screen and over a ¾ inch screen is nut coal, and that going through the ¾ inch screen is slack.

The boiler plants are equipped with the modern type of return tubular boilers, of an average of 150 horse-power each. In some few cases water tube boilers are used. Wherever possible or practicable, central electric power plants are located, and from a plant of this kind power is distributed to, in some cases as many as eight mines and for a distance of as much as 4½ miles, operating mining machines, locomotives, stationary motors used in the operation of rope haulage, blacksmith and machine shops, pumps and ventilating fans. In the operation of fans there are used variable speed motors with automatic self starters.

In the drainage of mines, which in rare cases is by gravity, there are many pumps used, mostly electric driven, of various types—piston, plunger and centrifugal. Electricity has very much simplified the drainage question, as it can be carried great distances and to points where steam could not, under any condition, be used, and is a much more economical power for this purpose than compressed air. Pumps used in the mine vary in capacity from 90 gallons to 1,000 gallons per minute, and work against heads varying from 25 to 400 feet.

The ventilation of the mines is an all-important consideration, as the law requires, in gaseous mines, that not less than 150 cubic feet of air per minute be provided for each man employed and that the mine be kept clear of standing gas. Aside from the legal requirements in the way of ventilation, the operator of the present day knows that it is to his advantage to supply an abundance of fresh air and have it properly distributed to the working places of the mine, to keep the mine in a safe and healthful condition for the men to work in. The introduction of electricity has simplified

the ventilation problem in many cases, as it has the drainage problem, being easily carried to any point, and auxiliary fans can, in many cases, be installed and operated at a small cost.

DISCUSSION.

The Chairman: Now we have heard what Mr. Moore has said, and I would like if possible to get a little topical discussion. We have with us Mr. Myers, from Philadelphia, who is pretty familiar with coal. Will Mr. Myers be good enough to open the discussion?

H. K. Myers (non-member): As Mr. Moore says, he has furnished plenty of material for discussion, because mining is made up of so many problems that it is pretty hard to discuss them all in one evening. Electric, compressed air, and rope haulage, especially, and pumping, would be interesting in themselves.

HAULAGE.

I have been connected with mines for 25 years and have made more or less of a specialty of hauling, also of compressed air and electricity. And it is surprising to see what has happened in the last 15 years in the way of electric haulage in the development of mines. Previous to that time if we got a tonnage of 1,000 tons a day it was considered quite an output, and if we got 2,000 it was considered very large. At the present time there seems to be no limit. The Vesta Coal Co. is doing about 8,000 tons daily. But it could not be done without electric haulage and electric locomotives.

Of course, there are conditions where rope haulage is really necessary; on heavy grades and other places where air locomotives are very advantageously used; where there is a large amount of gas and sparking might be dangerous.

Some years ago I was down in Kentucky and saw them running a haulage with hemp rope over a drum about 12

inches in diameter. I asked them why they did not use wire rope, and they said it was no good. It seems that some one had sold them a wire rope, and in order to give them a good strong one they had put in an iron center; and on a 12-inch drum of course in a few days it was all broken to pieces. That was fifteen years ago. It is remarkable how crudely some of the coal mining was done; cars that required anywhere from twenty to fifty pounds draft to a ton; tracks made up any way at all; and it was really killing mules hauling the loads. When they got locomotives in the mines they had to fix up the tracks; the locomotives would spread the rails and smash up things generally. And there has really been a gradual growth, until now they have things in a shape that is first class. The only thing they lack is automatic couplers on coal cars, which would save a great deal of time that is now lost in coupling up, and I think we will get them before long.

Chairman: I would like to ask Mr. Myers how near they get the electric locomotives to the actual workings.

Mr. Myers: Seven or eight years ago I built possibly half a dozen storage battery locomotives and they were ideal if taken care of. But at the present time, of course, they are using cables and pushing the cars to the mains of the mine. The General Electric, and other companies, are building locomotives on those lines, and using a cable and a drum; usually single conductors, and a T rail in the rooms, the current returning on the T rails; locomotives gathering and no mules in the mines. There are quite a few mines where collecting is done entirely with electric locomotives, and I know three mines where they are handling an average of 130 loaded wagons per locomotive per day, with an average haul of 2,000′ from the face of the room where they use one car in each room. There are places where they can place two cars in a room. Generally those cars hold two tons, which means 250 to 260 tons a day per locomotive with single cars over a round trip haulage of approximately 4,000′. I know a few

where they use horses, and they would save about $60 a day in operating by using electric hauling locomotives, after charging up all the cost for interest, depreciation, etc. It is a saving of $60 on 1,500 tons' output; this is quite an item. It requires, of course, quite a large outlay in the beginning, T rails in the rooms, and bonding those rails, a power house, etc., but it pays to have the installation.

Chairman: Do I understand that the electric locomotive is superior to the compressed air plant simply on account of efficiency?

Mr. Myers: Oh, no. The compressed air locomotive is cumbersome, and in order to work it is necessary to have storage tanks. A locomotive that weighs, say 15 tons, to run a mile, there would have to be approximately two tanks 16' long and 6' high and charging stations every mile, and if your air leaks or otherwise gets low between stations, you would have to cut loose from the draft and run out to the charging station and get loaded up; and, of course, you have to have double strength pipe in the mine for the storage system, and it is rather expensive. But it is very nice under some conditions. You have to have large head room, and it is a little more expensive to install and very much more expensive to operate. The efficiency of a compressed air plant is not much over 10%, I think, whereas with an electric haulage plant you ought to get 50 to 60% from boiler to actual work done.

Mr. Moore: Mr. Myers has mentioned the fact of the Vesta Coal Co. handling something like 8,000 tons a day. But I noticed he did not say anything about the fact that they use about 37,000 feet of rope haulage in taking out that 8,000 tons, in addition to the electric apparatus.

Mr. Myers: They laid the mine out originally for complete electric haulage, but from the heavy grades outside they found it was better to put in rope haulage than to use locomotives. An electric locomotive on heavy grades has to haul itself up each time and the hauling power of locomotives on grades decreases very fast as the grade increases. A ten-

ton locomotive has a tractive effect of about 4,000 pounds on the level. When it goes to a 3% grade, weighing 20,000 pounds itself, it requires about 800 pounds of that tractive effect to haul itself up, and leaves only 3,200 pounds to haul the train, and each time you make a trip you are hauling a lot of dead weight.

Speaking about rope haulage, I installed one about 23 years ago that was quite unique. I don't think there was ever anything like it before or afterward. We had a contractor's locomotive in the mine, with two mines about a mile and a half from the tipple. We made a set of friction wheels on a side track connected with a drum which drove the rope. The locomotive brought the cars up from the tipple to the mouth of the mine, then ran on the side track where the friction wheels worked and by means of them drove the cars into the mines. And when the loaded cars were again brought to the mouth of the mine, the engine coupled on and took them down to the tipple, and repeated this operation at another mine. And all we had was one steam locomotive, one engineer and one trip rider to handle 1,500 tons a day from two mines over a maximum of 5,000 feet inside haul and heavy grades.

H. J. Lewis: On the matter of haulage, the transportation problem in a mine is a pretty big one. Nearly everything else hangs on it. You can spread out the miners and produce almost any amount of coal, and you can arrange the outside to take care of about as much coal as can be dug. But to always deliver that coal from the working face to the outside with regularity so that the men inside will always have empty cars, and the tipple will always have coal, is one of the hardest of propositions for the superintendent. Laying out of the haulage should be one of the most carefully thought over things about a mine. There is no single type of haulage that will suit all cases. There are some places where electricity is the thing; there are other places where compressed air is the thing; and there are other places where your coal is

below the railroad and you can not reach it except by heavy grades or a vertical shaft, and there the rope is the thing. The drudgery of elevating coal, that is where it becomes drudgery on account of its depth below the point of delivery, without sufficient distance to make an easy grade; that drudgery must almost always be accomplished by the rope, in some cases supplemented by the chain. But a chain haul is a thing to be used rather sparingly, as it adds one more point of grief and a possible point of failure, though it is necessary at times.

Chairman: I was around a number of Ohio mines some time ago and I noticed that most of them had mules to haul instead of horses, and I asked why. They said that when a horse hits its head it throws it up and when the mule hits its head it puts it down. Is that so, Mr. Lewis?

Mr. Lewis: Any miner will tell you that, that mules take care of themselves very much better, not only in case of hitting their heads but in cases of being jammed between trips or anything of that kind, they sneak off to the side and get out of the way very much better than horses. The mule is more shifty than a horse is.

CHAIN HAUL.

Mr. Flanagan asked me to explain what I meant by a chain haul. In places where you cannot connect the tipple with your mine on a grade which you can operate with rope, we sometimes use a chain and sprocket, with hooks which engage either a lug on the car or some times the axle.

Mr. Moore: At the Duquesne coal mine, Edgewood, P. R. R., a main haulage of unique type has continued in use for many years. It was devised by Mr. James B. Corey, the former operator of the works. A 1″ or 1½″ wire rope lies dead on the centre of track, being fastened to the ground at both ends. But there is slack enough to give it several turns around two large grooved friction wheels that are mounted with engine and boiler, to drive them, on a flat

car. This "locomotive" thus warps itself along the line of rope and pulls a train of mine cars.

Chester B. Albree: Like an arrangement on the River Rhine. They have a chain lying on the bottom of the river and it goes up and takes three or four wraps around a drum on a boat and goes back into the river. They can go up against a very heavy current. They only utilize it going up, and use the current coming back down. It is very effective. They can use compound engines, and it is astonishing the length of the tows they can pull in that way against a very stiff current.

F. Z. Schellenberg: For heavy work the chain haul has cost as much as $5.00 per link. A light chain haulage (in Manifold shaft No. 1) brings the loaded cars to shaft bottom from locomotive parting, and another returns the empties, the grade being untoward. This power arrangement has proved advantageous over the handling at the other hoisting shaft bottom, with grade favored by gravity. I had to do with the installation and steady operation for many years of the first chain haulage hereabouts. It was brought to Westmoreland county from the Anthracite region, and was a small inclined hoist, driven from head sheave of hoisting shaft, but always the one way (although the driving sheave necessarily alternates in direction) for cars from the tipple, finally by gravity, either as empties to pit mouth or as loaded with slate to be run to spoil bank. The late Robert Ramsey devised an automatic switch (with counter weight and bridle rails, with castors under them, riding on inclined throw plates) that beautifully discriminates between the empty and loaded cars that come in procession to the brow.

The alternating reversing in driving, converted into continuous driven direction, before mentioned, is illustrated in diagram No. 48 of the book "507 Mechanical Movements," by H. T. Brown, which shows the principle, although the opposite in action.

MACHINE MINING.

Chairman: There is one point in the paper that has not been taken up at all, the machines used in the mining. I would like to hear from Mr. Lewis on that subject.

Mr. Lewis: As to the cutting of the coal I think there is a basic statement that can be made as regards the mechanical means. When ever the coal can be cut with a primary rotary motion, electricity is the way to do it; and when it must be cut with a reciprocating motion, compressed air is the way to do it. As to the conditions that bring about the use of the electric machine which uses rotary motion, there must be a fairly good bottom. If the bottom comes up into the coal, as it does sometimes, rather unexpectedly; when you run into that with any form of cutter bar machine, I do not care what it is, you are going to have a good deal of trouble and it will be very expensive to keep up the machines. While if you have a good bottom where you are always cutting in coal, the rotary machine is undoubtedly the best; because anybody that has ever seen a punching machine work and has seen the hard work of the operator, knows that he certainly would last longer with a machine which more nearly takes care of itself while running.

Another thing is the character of the coal recovered from the cutting. The electric machine make a small slot, but it reduces the coal to what is called bug dust, while in some kinds of coal the other machine cuts down more coal but makes a smaller percentage of dust. There are so many things to consider in adopting a type of machine that you could hardly mention them all in one evening; they differ all over the country. I do not think our electric friends have ever developed a very good reciprocating machine as yet for any kind of drill work; at the same time they have given us the best and most adaptable forms of rotary motion conveyed at the end of a wire.

Chairman: Suppose you do want an air machine and it is

several miles inside the mine, how are you going to get the air in there?

Mr. Lewis: We hardly ever get several miles in, but sometimes go as far as 10,000 feet. Following the pipe it is sometimes farther. We do not get the air in very successfully on long distances.

Chairman: I was in one of the mines in Wheeling some time ago, where a small truck, on the same main track, carrying a small electric driven air compressor, was used to supply air to the punching machine. This truck was carried within 30 or 40 feet of the puncher and moved about from place to place. This does away with the necessity of carrying the air through such long pipe lines.

Mr. Myers: That has been tried at different places, but the great trouble has been that you do not have water for cooling the compressor, and the air in the mine is charged with coal dust and it gets in the cylinders with the air and cuts them.

Mr. Lewis: It is a long way around the bush to first generate the electricity outside, take it inside, stand the losses on that, and also the losses which must necessarily occur with compression on a small scale, which increase quite rapidly as you go down the scale. A big compressor working with compound steam and on compound air, thus cutting down the clearance loss to two atmospheres instead of five in the air cylinder, will run with very good economy. But the kind of compressor you could run around on a buggy and drive with a motor would be a very wasteful machine in itself, and driving it by a small motor through the wire would carry all the loss of a small motor and transmission. This in addition to the point you mentioned that it is a mighty poor place to run a compressor.

Mr. Schellenberg: I might say of the punching machine that it can work where the large electric machine could not work, that is, where the roof requires propping. An electric machine has got to be big now days or it is not economical.

Such a machine requires about 12′ free space to move one frame over the other, and the roof is in very many cases not good enough to stand such an open space unpropped. With a punching machine one can go between props just as a hand miner does. But all the coal is not mined by machinery. You cannot mine out between rooms with machinery. So there is a disposition to leave rib coal in the ground, that is, to mine out what they can get with machines and let the rest go. It requires some hand mining to get all the coal. Then there are no machines in the coke regions. They do not undermine there; they blast from the solid face in narrow headings and rooms and take out all the rest of the coal systematically in well ventilated retreats.

Mr. Lewis: That coke region is rather a special condition, as they do not care how small the coal is.

Mr. Schellenberg: Machine mined coal is never as large as hand mined coal was or is, because it is slaughtered with the powder in heavy blasting.

J. M. Armstrong: It is also followed by a different class of miners than the hand miners of a number of years ago.

FLOODED MINE.

H. W. Myer: There was a unique occurrence related to me the other day relating to a case where a mine was flooded. The shaft was 150′ deep and the mine was flooded as well as the shaft. They drilled a hole near the shaft 12″ in diameter, drilled it down to and through the coal and about 150′ deeper. Then they placed an 8″ pipe in this hole without casing and on the outside of the 8″ pipe a 3″ or 4″ pipe, with an elbow extending up under and into the other about 2½′. This outfit was lowered into the hole to the bottom of the 300′ hole. Then they connected the 3″ pipe with a compressor temporarily set up and forced air into that pipe with 80 pounds pressure. They found that they could lift water out of that 12″ pipe in a solid stream and lower the water rapidly, and did so until the water

was lowered to the level of the coal; then it ceased to work. And it was very simple.

Mr. Myers: That is on the principle of what they call an air lift.

Chairman: I saw half a dozen discussions of the air lift in the London Engineering, I think it was, and nobody seemed to give even a good theoretical discussion of it.

Mr. Schellenberg: I can say confidently and without any favor of any patentee that the easiest way to unwater a shaft on a large scale is to dip it out with boxes on the cages. There is not patent on it. It has been done in the anthracite regions as a steady way of pump shaft work. I had the experience of unwatering a shaft that way and it worked very well. The bores filled themselves from the bottom; and a little wooden lever was constructed to knock at the top, and lifting a gate on the box, to let the water out in a trough. It is relatively cheap and you can rapidly get and lift a full load of water.

Mr. Lewis: You have the advantage of lifting nothing but water, all the rest runs in balance.

Chairman: Does anybody know whether pulsometers have been used?

Mr. Schellenberg: They are very wasteful of steam, but will raise any kind of water and grit of any kind.

Mr. Myers: One of the troubles of the pulsometer is that when the pump sucks dry you have to reprime it; it will not pump automatically, at least that is my experience.

VENTILATION.

Mr. Schellenberg: Compressed air is a very good adjunct even where they do use electricity. Anybody that has a compressor likes to hold onto it and use it for supplementary pumping in a small way; and it can be carried down to the very smallest. It can be used for a little automatic pump for unwatering a room in the bail hole instead of running a wagon

in for bailing into. That cheap little air pump seems to have gone out of use. It is described best as a half barrel beer keg, the bottom replaced by a performated copper bottom; on top is a balance for valve that may float open. When the water rises up inside it turns on the air. There is ⅛" of air only turned on that drives all the water through a little pipe to where it discharges itself by gravity, and then lets the valve seat itself; it may work day and night without any attention.

Then where entries are driven forward and there is compressed air in the mine the steam pump can be followed up and used with air very favorably. And "sparking" electricity, it may be mentioned, cannot be used in gaseous mines for any purpose, under present law.

Chairman: But I know a good many gaseous mines that do use it, at least they are so-called gaseous mines. How about that?

Mr. Schellenberg: Of course, there is a distinction to be made, where the mine has been ventilated sufficiently so that there is no gas present and open lights are permissible.

Chairman: I would like to ask Mr. Schellenberg are there any mines in Ohio that use a furnace for ventilation?

Mr. Schellenberg: Yes, and here, too. And it may not be generally known that the furnace is the most economical for very deep mines. The greater temperature at depth favors continually what we call ascensional natural ventilation.

STEEL MINE CARS.

P. S. Whitman: I would like to ask if there is any future in the steel mine car. A number of the gentlemen I have spoken of using heavy electric locomotives, and it would seem that when the locomotives get heavier and the trains and cars get longer, something will have to be done to develop the strength of the individual car. The mining car, as familiar to me, is the crudest sort of carriage. Scarcely anything at all is done to reduce the friction. I have often wondered if it would not pay to use roller bearings on trucks.

Mr. Myers: The present mining car with the oil box cast in the hub, under ordinary conditions runs pretty easy. I have tested cars that only ran 14 lbs. to the ton; but often where they are allowed to run down and never looked at, the axles worn down to two-thirds diameter through lack of oil, it will run as high as 50 lbs. But in the mine you have to have a car that can in the first place be built pretty low. I think the steel cars are coming. Mines using them are finding them very satisfactory. But the wooden car built by the average man has a heavy frame and draw bar, and for pulling I do not think they could increase the strength very much. A 4x¾" draw bar will stand any draw bar pull you can put on it. In pushing it is apt to buckle. The steel car is an ideal mine car; the only trouble is it is too expensive.

Mr. Lewis: I do not see how you are going to avoid steel cars when the lumber gives out. Whatever we use will likely cost more than the cars of today, as the car of today costs more than that of ten or twelve years ago.

Chairman: I do not see how much can be gained from the saving of dead weight by the introduction of steel cars, because unless large weights are carried similar to the railroads, you do not get much advantage. The ordinary wooden car on the railroad has about 33% of the load dead weight, while the steel car carrying more tonnage runs down as low as 28 to 30%, but in order to do that you have to have very heavy loads. In other words, the steel car will have less weight than the wooden car carrying the same tonnage, but when you come to the small loads that you have in the mine this will not be true.

Jno. A. McEwen: Isn't there another condition in regard to the preservation of the steel in a car? The conditions in the mine are such as to make it pretty hard on steel, and the friction of the coal in dumping, etc.

Chairman: Some years ago I had occasion to examine a good many steel cars that had been in the coal service, and I also saw some cars that had been running some fifteen years

in England, which were made in Leeds by the Fox Pressed Steel Co. The cars did not show any effect from rust to speak of. The cars I looked at in this country were those hopper bottom drop type, and inside they were bright and smooth from the sliding coal, and on the outside they had been painted and there was no rust. The cars in England had not been painted, and of course showed some rust. But if you will stop to think that something lige 1'100" of steel will make perhaps ⅛" of rust there is nothing like the amount of steel gone as the appearance would indicate. Those pieces I looked at were probably ¼" thick originally and had 15 or 20 years of service under pretty severe conditions and the slight dimunition in thickness I don't believe, affected the strength of the car in any way. Any way, a car is not a storehouse; you don't expect to put coal in it and let it stand. I doubt very much if you put a wooden car in the same conditions if it will last as long.

H. W. Myer: I have been in a good many mines where the water was so sulphurous that I would hate to trust a steel car in there any length of time. Rails last in good condition only a few weeks, and the less steel or iron there is about a car the better.

Mr. Whitman:. I was connected with the building of some cars for the Cambria Steel Co. for their mines at Franklin, and we built them out of 3'16" plate. They used steel cars because at the mouth of the mine there is a very steep grade and all the wooden cars in service were knocked to pieces by cars coming down the grade and hitting a line of cars on the track and the wooden frames were splintered all to pieces. We got the cars strong enough so that the under frames stood that shock, and the cars have been in use a number of years very successfully. Of course, they are expensive and they use them only because it is absolutely necessary on account of this steep grade.

Mr. McEwen: Why is it that an end dump car is always used? Is it because of the expense of a hopper bottom? It makes a rather expensive apparatus for elevating one end of the car.

Mr. Lewis: I suppose one reason is that we can get coal on to the screen with less breakage from the end of the car than by any other form that will clear the car quickly. We must handle those cars in from 40 to 48 seconds in order to get action on the screen, and an end dump clears so much more promptly that any other that would work with equal speed. Some of our British friends roll the car clear over and dump out of the top, but that makes it necessary to drop the coal into a big hopper before you can get it on the screen. Every extra foot that coal drops adds to the breakage, which is always a consideration with bituminous coal.

Mr. Schellenberg: Are you aware that they intermittently dump now, moving the car back and forth so as to slowly pass the coal out of the car on the screen?

Mr. Lewis: Yes, the old cross-over dump does that fairly well, too.

Mr. Myers: One of the objections to the drop bottom mine car is that the axles have to be set close together to accommodate the short curves going into the rooms, you cannot get any sort of opening in the bottom of the car to discharge properly.

Mr. Lewis: The bottom provides about the only stiffness we have in the cars and if that is cut for drops you have nothing left.

Mr. Armstrong: I notice Mr. Schellenberg has made the same mistake miners of this district have in relation to the steam dump. The only steam dump in this district that I know of is simply an adaptation of the Phillips cross-over dump. Instead of a smooth sword it has what some of the miners call a devil's tongue, the sword is notched on either side and this works on a center that is operated by a lever the same as the Phillips cross-over dump. The only application of steam to it is in throwing the dump back. You have to have so much overhang at the dump that the car will not right itself and the ordinary steam cylinder is used for bringing it back to position.

Mr. Schellenberg: There is one being made with a hydraulic arrangement. The idea is to not throw the coal on the screen all in a heap, but to discharge it in some detail so it will screen properly while at the same time the lumps are less broken.

Mr. Armstrong: The same can be obtained with the Phillips dump in the hands of a competent man.

Mr. Schellenberg: Then, too, it may not be generally known that the general preference is to load the car endwise where it can be done either by hanging an apron to turn the coal at right angles at the end of the chute or building the chute lengthwise of the track, so that the coal may arrange itself lengthwise of the car and not strike the opposite side as it enters, which is pretty hard on cars. And also the coal makes a better appearance on the top of the car.

SOUTHERN COAL FIELDS.

Chairman: I heard it stated that the southern coal fields were some day going to displace the Ohio coal fields. Is that true?

Mr. Schellenberg: As far as I know that cannot be true.

Chairman: Is that coal a good quality?

Mr. Schellenberg: Well, yes. It is different though. The coal is better than the Pittsburgh in some particulars, but there is none other so uniform and reliable and so easily gotten. There is coal mined in Ohio that is better for domestic purposes than Pittsburgh coal because it does not make the soot, but it is all in smaller veins.

Before the Pittsburgh Section of the United Chemical Society, May 23, 1907.

A New Shaking Device for the Chemical Laboratory.

BY J. M. CAMP.*
Member.

The alchemist of old failed in his search for the philosopher's stone, whose mere contact with the baser metals was to transmute them into gold and silver. Nor has the later day chemist, for obvious reasons, found this magic pebble, but he has found the secret of changing the baser oxides into the equivalent of gold and silver. And when we compare the laboratories of the present day with their delicate apparatus, and those of the ancients, with their meagre supply of crude reagents, whose apparatus included only forge-like furnaces and retorts, we can not but marvel at their persistency in the face of such difficulties and the wonderful results they obtained. In those days the laboratory was more like a forge shop, now it is approaching more and more to the mechanical, with its automatic samplers, grinders and stirring machines doing the manual labor, leaving the operator free for the more delicate manipulations. And in the present day equipment to keep pace with the ever-increasing demands of the mills and furnaces, one is called upon to use every facility whereby quickness and accuracy may work together towards the accomplishment of the best results.

Among the various pieces of apparatus going to make up the equipment of the modern laboratory, it is the purpose of this article to describe the latest appliance, in the shape of a shaking device. It was designed and is particularly adapted for the purpose of hastening the precipitation of phosphorus by the well-known and almost exclusively used molybdic acid method, and in the solution of steels or pig irons for carbon

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combustion. But it is equally useful where agitation is desired in a flask for either dissolving or precipitating. As can be seen from the photographs, it consists of a frame supporting a vertical shaft, which is revolved by a six-inch pulley wheel. The upper part of the shaft is bent slightly from the perpendicular. Encircling the bent portion of the shaft is a hub

which in turn supports a flat disc on which the flasks to be shaken are attached. The hub and disc are prevented from turning, when the shaft is revolved, by suitable teeth on the underside of the hub meshing into corresponding teeth on the top of the supporting frame.

On revolving the shaft the motion of the disc is ideal for the purpopse intended, and can be best likened to the simultaneous pitching and tossing of the deck of a ship in a tu-

multuous sea. With each revolution of the shaft a wave travels around the flask or flasks on the disc exactly as in hand shaking, and by increasing or diminishing the number of revolutions the number and intensity of the wave movement is controlled. To obtain the maximum agitation and still retain the solutions in the flasks, without corking, from one

hundred to one hundred forty revolutions per minute has been found very satisfactory. The disc is made to hold six flasks, any one of which can be placed in or removed from the machine in a fraction of a second. The gripping device is movable, up or down, enabling it to be quickly adjusted to hold any size flask from a six ounce to a twenty-four ounce Florence or Erlenmeyer. The electrical power required to oper-

ate is twelve-hundredths of an ampere on 250 volts; about the equivalent of the one twenty-fifth horse-power, or less than the average desk fan motor is consuming, so that with the proper counter shaft to give the desired number of revolutions, any source of power may be used.

Heat can be applied to the apparatus if desired by means of a circular burner, but it has been found that by adding the hot liquid to the flask, or heating the contents of the flask before placing it in the machine, the same end is obtained.

The advantages of the machine over hand shaking are to the chemist only too obvious. During the time of shaking the operator can be doing other more profitable work, with the assurance that aside from being relieved from the fatigue of the operation, the machine is not shirking the job—as is the natural disposition of mankind—resulting in false analysis, while with the machine the reverse is the case, it is always allowed to do its full quota of work. Then under its constant conditions, in phosphorus precipitation, for instance, a precipitate of like crystalization is always obtained, aiding materially its estimation by judging its bulk, as is the practice in most busy open-hearth steel works laboratories.

The simplicity of the machine, its ease of operation, quietness, and the readiness with which the uasks can be placed in and removed from the apparatus and the fact that they do not need to be corked, should commend it to anyone. It will fill a long-felt want.

Application has been made and the claims granted for a patent covering the ideas embodied in the machine.

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

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THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

June 18th, 1907,
S. M. Kintner, President.
In the Chair.

Sewage Problem of Western Pennsylvania

Introductory.

BY MORRIS KNOWLES,*
Member.

The occasion for this meeting came about in a peculiar way and it is worth while giving you a history of it, in order that you may see how important matters sometimes grow out of trivial circumstances.

Some time ago, I received a letter from my friend, Dr. George A. Soper, of New York City, stating that he had recently made some interesting investigations in regard to a chronic typhoid bacillus carrier. Further correspondence and discussion with the Programme committee brought about a belief that it might be well to present the facts of such study before our Engineering Society. In this connection, it was thought desirable to show the lesson that, if such occurrences are likely to happen, no raw river water supplies are safe unless sewage be treated; for such contamination may happen at any time, even if there be no sickness to cause warning. As we had many talks on this subject in regard to filtration

* Chief Engineer, Pittsburgh Bureau of Filtration.

of water, it was considered best that we should have some discussion about sewage disposal. The speaker, therefore, at the request of the committee, promised that he would arrange and be responsible for the programme for such a meeting.

After preparing for the meeting upon this subject, it was learned that Dr. Soper could not be present, on account of a prior engagement to speak at the American Water Works Convention at Toronto, Canada. It was not thought wise, however, to postpone the event entirely and therefore the original arrangements were continued, viz.: To secure a statement of the recent growth of public sentiment, the causes and effects of the recent legislation in this State and necessity for separate sewer systems the treatment and disposal of sewage. With this in mind, we communicated with the State Department of Health and were extremely gratified to secure Mr. F. Herbert Snow, Chief Engineer, to speak of these matters and he will give us an interesting and valuable account of this phase of the subject.

In addition to this it was thought wise to secure facts in regard to the present sewerage system of the City of Pittsburgh, particularly as the problem of revision will arise quickly, if it becomes necessary to revise the down town sewerage system, due to the construction of a Subway. Mr. I. Chas. Palmer will present this phase of the subject for consideration.

As Dr. Soper cannot be with us the speaker will give you briefly a general account of this peculiar source of pollution which has attracted so much attention.

In the summer of 1906, six persons of a household of eleven at Oyster Bay, L. I., were stricken with typhoid fever. Considerable investigation was undertaken, most of which was indeterminate, but seemed to indicate that all of the usual customary causes of typhoid fever could not be thought to be the right one. Somewhat later on, Dr. Soper in making his investigation, found the only unusual occurrence in this family was the advent of a new cook. For some time nothing was known about her previous life or condition, as she was reticent. It

was finally found that she had, during five or six years, worked in eight families, in only one of which typhoid fever had not occurred. The actual statistics are that there were 26 cases in these families in which she had worked and one death and frequently she was the only person in the family not taken ill. In all cases the families had normal homes in good surroundings and lived in situations where typhoid was not prevalent.

In March, 1907, due to the very extraordinary facts, the New York City Department of Health took the woman into custody and, upon making a careful study of her excrement, it was found that bacillus typhosus was always present. We have then the strange condition, of a person in apparent normal health who is a source of contamination and pollution whereever she may go. The dangerous part of it is that, appearing well and not known to produce disease germs, she is all the more dangerous and it shows that we can not depend upon simply taking care of our sanitary sewage when sickness occurs, but vigilance is always necessary.

Some facts in regard to the general present condition of the treatment of sewage in the United States will very likely be of interest. The speaker draws largely from the excellent paper read by Mr. George W. Fuller, C. E., before the International Engineering Congress, held under the auspices of American Society of Civil Engineers, at St. Louis, in 1904.

The greater portion of the vast population of the United States disposes of sewage by dilution or dispersion in water. Of the 28,000,000 of urban population in the United States in 1900, practically 73 per cent disposes of sewage into inland streams or lakes; 23 per cent by similar disposal into the sea or estuaries of the ocean, and the remainder, amounting to 4 per cent, are treating the sewage before it runs into the bodies of water mentioned. In 1890 there were only about 20 disposal plants in the country and these were a few years old only. In 1900, this was increased to about 90 purification works. Of the cities and towns of over 3,000 population, there were 1,100 out of 1,500, in 1902 having sewerage systems of some sort or another; so we can readily see the small percentage which

have yet begun to face this problem of purifying the municipal wastes.

The necessity for this is becoming more and more urgent, as population increases and refuse in our streams becomes more and more noticeable. It is important to notice, however, that almost all of our works for sewerage purification, particularly the larger ones, have been the result of careful investigation, and in some cases experimentation, before deciding upon the particular treatment to be used. This is true, even more than for water purification, for the best system is dependent upon the character, strength and times of maximum flow and character of the trade wastes in the sewage.

It is not right that I should burden you longer, when there is so much of direct interest to be brought before you by the other speakers, but trust this has been sufficiently outlined to show why this problem is of such urgent necessity and why it should be early studied in our community; in order that we may meet the conditions, even before they become too unfavorable.

Administration of Pennsylvania Laws Respecting Stream Pollution.

BY F. HERBERT SNOW,*
Member.

To appreciate and hence justly determine whether one shall sympathetically uphold recent legislation affecting public health relative to water supply and sewerage, a brief review of old laws is necessary.

Prior to the classic typhoid fever epidemic of Plymouth, Pa., in 1885, matters pertaining to public health were not directed or controlled by a central State body for the reason that no such central body existed. The law of 1828 prohibited the pollution of Fairmount reservoir in Philadelphia, and the law of 1832 prohibited the pollution of the Schuylkill river

* Chief Engineer of State Department of Health.

between the dam at Flat Rock and the dam at Fairmount. Also the general law of 1874 prescribed penalties for the contamination of any reservoir belonging to any city or borough in the State. These and the laws permitting the abatement of nuisances by local boards of health within coroprate limits, were, of course, totally insufficient to protect public water supplies.

Then came the startling lessons of the Plymouth scourge, followed by immediate legislation. The story should not be forgotten.

The borough of Plymouth was, in 1885, a new, booming coal mining town, of about 9,000 population, located in the beautiful Wyoming valley district of the anthracite coal fields on the north bank of the Susquehanna river, three miles below the city of Wilkesbarre.

The dwellings were largely upon the hillside, the ground rising somewhat abruptly back from the river, so that good surface drainage naturally obtained. Sewers were unknown. Household wastes were deposited in back yards, cesspools and privies, and not infrequently into street gutters. Yet in spite of this the borough's health differed not from neighboring communities similarly inhabited. At no time prior to the epidemic in April, had typhoid fever been prevalent to an abnormal extent. This is significant in view of the town's water supply.

Previous to 1876, the drinking water had been obtained wholly from private wells and springs in the borough. After 1876 the supply was obtained partly from said sources and partly from the new water company's gravity sources which comprised a succession of impounding reservoirs, four in all, aggregating 10,000,000 gallons storage capacity, located in a ravine to the top of the Shawnee Mountain, overlooking the town; and partly from the company's auxiliary pumping service, by means of which raw river water was introduced into the system annually for periods of from 65 to over 100 days, when the mountain sources proved inadequate.

The reservoir water sheds were steep, rugged and practically uninhabited areas. Two dwellings only were there.

For ten years three hundred house connections with the old Wilkesbarre sewers had been contributing pollution to the river at a point two miles only above the Plymouth Station intake. In 1885, six hundred connections had been made to the Wilkesbarre sewer system, the remaining people, out of a total population of 30,000, using cesspools and privies.

The stream between Wilkesbarre and Plymouth has a rapid current. Notwithstanding its sewage pollution, the use of the river water at Plymouth and Nanticoke (immediately below), for drinking, had never been attended with serious results.

During the week of April 12th, an alarming amount of sickness became manifest in Plymouth. From fifty to one hundred new cases appeared daily. Apparently the outbreak was not confined to any section or class, all alike were attacked. The head symptoms were so severe as to suggest something besides regular typhoid fever. The earlier patients seemed to be brimful of poison. Upon the primary visit of the physician, they were found to be violently delirious and had very high temperature. After the first ten days, the epidemic settled down to the well recognized normal type of typhoid fever.

All investigators conceded that the water supply was the medium of transmission of infection, also that the well water had nothing to do with the causation of the disease, at least, in the early part of the epidemic. Typhoid appeared wherever public water was used and only there.

Water was pumped from the Susquehanna river into the mains of the part of the town bordering the river, between March 20 and 26, inclusive. Had this water contained virulent poison, the outbreak would have occurred to some extent within ten days, or between the 1st and 6th of April, which it did not. Besides, Nanticoke, taking its entire supply from the river below Plymouth, had less typhoid in March and in April than usual.

The cause of the catastrophe was located on the mountain slope, in a house situated almost immediately upon the bank of the stream between the third and fourth reservoirs. Here a patient, contracting the disease when on a visit to Philadelphia, had for many weeks been seriously ill with typhoid fever. The man returned home on January 2. On March 18, during a relapse, he had hemorrhages of the bowels of so severe a type that his life was despaired of. Not until April 12 did the attending physician discontinue his visits. The night dejecta had, without any attempt at disinfection, been thrown bodily upon the snow at the top of the high bank, at the bottom of which was the stream supplying Plymouth. The day dejecta were emptied into an overflowing privy vault, level with the surface of the ground, where they were frozen and held in an accumulated mass ready to be released and washed into the stream. Had the doctor or nurse known that the small stream was the town's supply of drinking water, the history of the epidemic might never have been written.

A considerable thaw began on March 26 and continued until on April 4 the temperature reached 70 degrees Fah. This caused the breakup of ice and the melting of snow and the freshet which swept everything along with it. Previous to March 26, the month was the coldest of the winter.

The river pumps were stopped on the 26th and from that on the town was supplied by the mountain stream and so through this medium the poison was distributed to the consumers.

The epidemic continued through the spring and summer and totalled 1,104 cases and 114 deaths. Of the cases, 713 were in April, 261 in May, 85 in June, 31 in July, 15 in August and 1 in September.

The later cases in May and thereafter, were in a great measure due to secondary infection. Non-disinfection of stools and careless disposition of excreta prevailed in spite of the exigencies and warnings. The people through fear of the public supply had recourse to old wells which were so located

on the hillside as to receive the percolating poison of nearby cesspools, or by direct surface pollution. So well water was one of the chief avenues of secondary infection, although flies must have played no mean part in the transmission of the scourge after its primary visitation.

The lessons to be noted are first, that the infection came originally from a distant city and was brought to Plymouth by one individual. Second, that from one single source of pollution on a watershed, otherwise uninhabited, may result a contamination sufficiently virulent to fatally infect the water supply of the whole town located miles away. Third, that improper disposal of household drainage in the town is a public menace to the health of the entire community, more especially in the presence of an epidemic. And, fourth, that a river water polluted with sewage from a city free from typhoid fever is less dangerous than a small swift running stream containing concentrated poison.

The Plymouth epidemic might have been prevented by a rigid enforcement of well known hygienic and sanitary regulations.

For ten years the American Public Health Association, the State Medical Society of Pennsylvania and other medical bodies had urged the necessity for the creation of a State Board of Health, but not until 1885, when the public mind was deeply impressed by the Plymouth lesson, were the senses of the legislative branch of government sufficiently aroused to the importance of the subject to establish an executive health department.

The purpose of the law of 1885 was set forth in the title "To establish a State Board of Health for the better protection of life and health and to prevent the spread of contagious and infectious diseases in this Commonwealth."

The general duties of the board were to supervise the interests of the health and lives of the citizens of the Commonwealth, to especially study vital statistics, make sanitary investigations respecting causes of diseases and disseminate

information upon these subjects among the people. Also to codify and suggest amendments to sanitary laws of the Commonwealth.

The efforts of the board were immediately directed towards procuring legislation for the protection of the purity of streams and other inland waters, more particularly of such as were, or were likely to become, the sources of water supplies for cities and towns. In this attempt the officials of water companies, public servants and the press rendered support. However, dread of interference with the manufacturing interests prevailed in the minds of the legislators, and although the State Board of Health continued to urge new laws, the first one of any importance was that of 1899 appertaining to the Schuylkill river and its tributaries, and empowering the State Board of Health to examine the water supplied to cities of the first class, for the purpose of ascertaining whether such water be free from contamination by human excrement, and to abate nuisances, providing therefor a cumbersome method which operated to practically exempt important major sources of pollution. The board tried under this law to proceed against the borough of Norristown, whose sewage was discharged into the river a short distance above Philadelphia. Strange to say, that municipality found a way under the law to prevent the State bringing the case into court.

The minor menaces were so numerous, the watersheds so large and the available funds so insignificantly small, that effectual work was stopped here also.

Meantime, municipalities all over the State were authorized to build sewer systems emptying into streams. Relative to the power of the board to enfore regulations to limit the spread of epidemics, the attorney general rendered an opinion in 1890. He said:

"The functions of the Board of Health are mostly of an executive and advisory character, and while they are quite extensive and involve a large amount of discretion, I do not think that they can be extended by any considerations of sup-

posed advantage beyond the plain import of the language used in the act. The powers committed to the Board of Health to abate nuisances and prevent the spread of epidemics are of a highly important and responsible character, to be cautiously exercised and on occasions of special emergency, and their execution is often necessarily attended with prompt and radical action in dealing with persons and property. I am, therefore, inclined to a strict interpretation of that portion of the statute which confers these powers.

"In my opinion, the power committed by the statute to your board to enforce regulations tending to limit the progress of epidemic diseases is confined to the case of the actual presence of such disease at some appreciable stage of development, or to that of a threatened visitation thereof, as for example, when the circumstances attending the course and progress of that kind of disease in other states or countries with which we have intimate communication through the avenues of travel and commerce, would justify a belief that the presence of such disease with us is imminent or extremely probable. Beyond that limit your powers would only be advisory. It is, of course, within the sphere of your duty at all times to recommend to the municipal or local authorities having the usual powers in matters relating to the preservation of the public health, the adoption of effective sanitary and preventive regulations and measures in anticipation of future or possible epidemics."

Hampered by lack of power to force reports of contagious diseases, its suggestions unheeded, and its hopes continually deferred, the board kept industriously at work disseminating information, pointing out dangers, urging reforms and ministering to the distress of unfortunate municipalities. This period in the history of State sanitation was one of most trying missionary effort, nevertheless an important period during which true principles were made known to the public. Then came the Butler epidemic. Its importance was tremen-

dous in results. The present generation must not forget the salient features of the case.

Laid out in broad streets and commodious house lots, with residences substantially built, cleanly surroundings, and good natural drainage and with a sanitary sewer system, a filtered public water supply and a thriving population of about 18,000, Butler to all appearances was a healthful place and the last to be afflicted by an epidemic. So thought its inhabitants. This false sense of security was dispelled too late and at a terrible cost.

In the memorable winter of 1903-4 the town's water supply was furnished principally by the Butler Water Company. Possibly 300 families were using water taken from shallow dug or drilled wells scattered over the borough, and about 150 families in Ward One were supplied with ground water by a mutual association.

The rest of the community relied on the Butler Water Company's plant whose sources of supply were surface waters taken from three place. One was from Boydstown reservoir (97,000,000 gallons capacity), seven miles above Butler, near the headwaters of the Connoquenessing creek; another was Thorns Run reservoir, 247,000,000 gallons capacity, 2½ miles above Butler, on Thorns Run, a tributary of Connoquenessing creek, and the third was Connoquenessing creek itself.

The creek watershed above the pump house and filter plant, located on the banks of the Connoquenessing, just above the point where the stream enters the borough of Butler, comprised 44 square miles of sparsely populated, broken hilly surface, of which 14 square miles were above the Boydstown dam, and 6.5 square miles were above the Thorn Run dam. The water from the latter was piped to the gravity supply main leading from Boydstown reservoir to the suction well at the pump house.

Prior to 1896, all of the company's supply was obtained directly from the creek and the raw water was pumped to a

3,000,000 gallon masonry distributing reservoir on the hill back of the town. Subsequently, up to July, 1902, Boydstown reservoir water was supplied unfiltered to the town. This reservoir was constructed to improve the quality of the supply, which had become polluted by salt water overflowing from abandoned oil or gas wells.

From July, 1902, to August 28, 1903, filtered Boydstown reservoir water was furnished to the consumers. The purification plant was built to furnish a clear, pure water at all times. Its addition to the water works system received general public approbation and was an advertised town asset. The plant consisted of six mechanical filters and appliances of approved design, normal capacity 3,000,000 gallons daily, filtered water delivered to collecting basin beneath.

On the said 20th day of August, the Boydstown dam was destroyed by a freshet. Between this date and November 15, on which the Thorn Run reservoir was completed and put in use, the town was supplied with water taken from Connoquenessing creek, through the emergency intake at the pumping station.

The filters were out of commission for 12 days, October 20 to November 2, to permit certain repairs and pipe connections to be made at the plant, during which time unfiltered Connoquenessing creek water draining from the entire 44 square miles watershed was pumped into the town of Butler. Also during the early part of October the filters were either stopped for short intervals or did inefficient work, since they passed water turbid enough to cause general comment.

After November 2, filtered water was again supplied.

The presence of typhoid fever on the area contributing to the town's water supply was not an unusual thing. In 1902 14 cases were reported as occurring there, yet no known harm came to Butler's inhabitants therefrom. Seventeen cases of typhoid fever were located on the watershed in September and October of 1903. Two were within 1,500 feet of the

water works intake and the most remote were seven miles distant.

It appears that in all of these 17 cases the nursing was done principally by members of the household and that disinfectants were meagrely used, if at all. Earth privy vaults, receiving the discharges of patients, were invariably located where a heavy rainfall might wash infection from them or the ground roundabouts into the nearby stream. Such a rainfall did occur on October 22 and 23, following a protracted dry spell of several weeks.

In September and October 4 persons were sick with the disease in one dwelling located on the west slope of the Thorn Run reservoir. The dates of onset were August 1, September 5, September 29 and October 25. The earth privy at the house was poorly constructed, the surrounding ground showed evidence of pollution, and drainage from the property would pass directly into the stream supplying the town. This was before the completion of the reservoir, so no opportunity for detention was afforded.

During the first week of November considerable typhoid fever in Butler was unofficially reported. The local board of health upon investigation found the four cases on the bank of Thorn Run reservoir and immediately notified the public of danger and advised the boiling of all water used for drinking. This was on November 9.

It was subsequently ascertained that 204 patients were bedridden with the disease on this day and that for 30 days prior to November 9 typhoid fever had prevailed enough to have caused alarm had the existing conditions been known to the board of health. So the poison had not been introduced into the system in one dose. Five days thereafter, on November 14, a prominent daily newspaper advised the public to set aside the board of health injunction to boil the water for the reason that an analyst had tested the waters and found the supply to be free from fever infection. In these five days 185

persons went down with the scourge and on the 15th day of November 110 people were stricken within 24 hours.

Uncertainty as to the true character and source of the epidemic prevailed until State aid was solicited and came on November 28, in the form of a proclamation, announcing the public supply to be the medium of infection and enjoining all to boil the water. On that date 983 cases of fever were ready to be enrolled on the pages of the history of this wholly preventable catastrophe, and at the end, January 29, 1904, 1,384 cases had occurred and 111 deaths. No trouble there has since been experienced.

Besides the 30 cases recorded outside of the borough and 41 occurring away from the district, but traceable to the Butler infection, in the borough 47 cases occurred in October, 976 in November, 222 in December and 32 in January.

The first infection followed the introduction into the system of raw or partially purified creek water, during the last part of September, or the first part of October.

The second and concentated infection followed the shutting down of the filter plant and the pumping of raw creek water into the system between the dates of October 20 and November 2.

All classes of people were afflicted. In fact, the sickness prevailed less among the poorer citizens, because most of them drank well water only and thus escaped the poison. Otherwise, the disease was evenly distributed over the water district.

Tests of the creek water taken at the pump house during December and January showed sewage organisms in 23 out of 38 samples. Examinations of samples of water taken from faucets at various points in the town during the same period showed a high rate of filter efficiency.

Tests of water taken from 66 private wells throughout the borough gave negative results.

The food and milk supplies were investigated. No relationship appeared between them and the epidemic.

The striking things about this renowned tragedy are, first, that the public sense of security afforded by the filters unhappily side-tracked general suspicion of the water supply; second, that the filter plant had been erected to protect the public health which it did prior to the epidemic and thereafter; third, that carelessness or stupidity during the making of necessary repairs and alterations to the plant was a contributory cause, nevertheless the calamity would not have occurred had there been a proper disposal of sewage on the watershed; and finally, that compulsory reports and prompt publicity of typhoid fever in the rural districts as well as in the town, would have forewarned the local and State health authorities and have checkmated the spread of the disease.

Thus the policy of limiting the State Board of Health to powers of an advisory character only, until the actual presence of an epidemic threatens everybody in the community, was vividly shown to be suicidal in the extreme.

The people very generally saw the need of active preventive measures, not measures of repression only; but it should not be represented that public sentiment was sufficiently elevated to force more than a recognition of its existence by members of the legislature. The old commercial interests which had dominated past legislatures on all matters pertaining to stream pollution, were still on deck. The times were ripe for the stroke of a master hand.

Benjamin Lee, physician, scholar and gentleman, for twenty years secretary of the State Board of Health, had prepared the way. It remained for Dr. Charles B. Penrose of Philadelphia to crystalize sentiment into drafts of laws and to successfully fight for their adoption and the appropriation of adequate monies therefor to ensure real results. In the annals of public health relative to water supply and sewerage in Pennsylvania, this marks a new era.

The Plymouth experience resulted in laws for State repression of contagious and infectious diseases.

The Butler experience resulted in laws for State prevention and repression of contagious and infectious diseases.

By the provisions of Act No. 281, 1905, entitled "An Act Creating a Department of Health, and Defining its Powers and Duties," the terms of the members of the old State Board of Health and the Secretary thereof expired: The new Department of Health now consists of a Commissioner of Health and an Advisory Board. The Commissioner of Health, in addition to the powers conferred by the new law has all the powers conferred and must perform all the duties heretofore imposed by law upon the old State Board of Health, or any member, committee, or officer thereof, including the Secretary.

Before passing to the consideration of the "Purity Water Bill" it should be noted first, that it is the duty of the Commissioner of Health to have general supervision of the State registration of births, marriages, deaths and diseases, and he shall prescribe and prepare the necessary methods and forms for obtaining and preserving such statistics, and shall secure the prompt and faithful registration of the same in a Bureau of Vital Statistics to be maintained as a part of his Department. Thus it is intended through this instrumentality, that the culminative infection of a water supply like Butler shall ultimately be impossible in the State.

Second, under Section Eight of this law and also Section Nine, the Commissioner of Health becomes in fact a power to prevent causes of disease and mortality so far as the same may be caused by public menaces and nuisances, more especially outside of the municipalities on the watersheds of the State.

The sections read as follows:

"Section 8. It shall be the duty of the Commissioner of Health to protect the health of the people of the State, and to determine and employ the most efficient and practical means for the prevention and suppression of disease.

"The Commissioner of Health shall cause examination to be made of nuisances or questions affecting the security of life and health in any locality, and for that purpose the Commis-

sioner, and any person, authorized by him so to do, may, without fear or hindrance, enter, examine and survey all ground, vehicles, apartments, buildings, and places within the State, and all persons so authorized by him shall have the powers and authority conferred by law upon constables."

"Section 9. The Commissioner shall have power and authority to order nuisances, detrimental to public health, or the causes of disease and mortality, to be abated and removed, and to enforce quarantine regulations.

"If the owner or occupant of any premises, whereon any nuisance detrimental to public health exists, fails to comply with any order of the Commissioner of Health for the abatement or removal thereof, the Commissioner, his agents or employees, may enter upon the premises to which such order relates and abate or remove such nuisance."

"The expense of such abatement or removal shall be paid by the owner or occupant of such premises, or by the person who caused or maintained such nuisance, and such expense shall be a lien upon the lands upon which the nuisance was maintained."

The Commissioner has apportioned the townships of the State into about eight hundred districts and has appointed an officer in each district to execute his orders relative to menaces and nuisances. So a regiment of trained men will soon be at work on Pennsylvania's watersheds outside of the boroughs, towns and cities.

Act 182, of 1905, entitled "An Act to Preserve the Purity of the Waters of the State, for the Protection of the Public Health" refers to water works and sewerage. Sewage therein is defined as "any substance that contains any of the waste products, or excrementitious or other discharges from the bodies of human beings or animals."

So slops, sink and wash waters come within the meaning of the term. The idea prevails that laundry water and drainage from bath-tubs is not sewage. To the contrary is the truth. Such wastes very frequently contain pathogenic poison.

Yet often they are discharged on to the surface of the ground near springs and wells, or into street gutters and thence to streams used below as sources of public water supply.

Some manufacturing wastes are not sewage as above defined; but if a menace to public health, they are subject to regulation at the discretion of the Commissioner of Health.

The law stipulates that no person, corporation or municipality shall place or permit to be placed, or discharge or permit to flow into any of the waters of the State any sewage except as specially provided; but the act does not apply to waters pumped or flowing from coal mines or tanneries. Neither does it prevent the discharge of sewage from any public sewer system, owned and maintained by a municipality provided such sewer system was in operation and was discharging sewage into any of the waters of the State at the time of the passage of the act.

The term "waters of the State" is defined to include "all streams and springs, and all bodies of surface and of ground water, whether natural or artificial, within the boundaries of the State."

The exception noted, however, does not permit the discharge of sewage from a sewer system which shall be extended subsequent to the passage of the act, the date thereof being April 22nd, 1905. Therefore, so long as a municipal sewer system, in use before April 22nd, 1905, be not extended, the law is not applicable, and the sewage therefrom may continue to defile a public water supply.

Of course, all sewer systems must be extended. What comprises an extension, is not a subject to quibble about. Evidently the intent of the law was to bring, as soon as possible, all municipal sewer systems under State regulation and control. Unapproved sewer extensions to an existing outlet whereby the volume of sewage discharged into a stream were quadrupled would defeat the object of the law and be contrary to the letter thereof. So also would a short extension. It is the principal involved which controls.

The law further provides that upon application duly made to the Commissioner of Health by public authorities having by law charge of the sewer system of any municipality, the Governor of the State, the Attorney General and the Commissioner of Health shall consider the case and whenever it is their unanimous opinion that the general interests of the public health would be subserved thereby, the Commissioner of Health may issue a permit for the discharge of sewage from such public sewer system into any of the waters of the State and may stipulate in the permit the conditions on which such discharge may be permitted.

The permit before being operative must be recorded in the office of the Recorder of Deeds for the county wherein the outlet of the sewer system is located.

In the administration of this law, the Commissioner is one of a tribunal of three to exercise discretion. A unanimous agreement is required.

The policy inaugurated is to bring about the abandonment of streams as carriers of sewage. All sewage must finally cease to be discharged untreated into any waters used subsequently for drinking purposes.

In a municipality whose borrowing capacity has been about reached, the erection of sewage purification works for the present is thus prevented. However, it is the policy of the Commissioner to require that municipality, or any other, in extending its sewers, to make such extension in compliance with plans contemplating treatment works in the future.

It is not to be supposed that every time a town wishes to make some petty sewer extension, a petition should be necessary therefor. A general application for sewer extension should be made in the first instance involving the question once for all of State policy for that particular municipality. State approval, under these circumstances, implies careful consideration of the problems involved. The principal one relates to the disposition of the sewage. It is not practicable to treat large volumes of mingled sewage and storm water owing to

the prohibitive cost. Usually it is cheaper and better to build separate sewers for sanitary household drainage and to provide other channels for the removal of rain water.

One proposition is not debatable, namely, that efficiency and economy dictate that sewers shall be built to conform to a comprehensive plan. Piecemeal methods are bound to cause trouble and expensive alterations and repairs. Those towns which have employed competent consulting engineers to lay out comprehensive systems and who have conformed to those systems, have usually found such a course to be profitable.

Even where a municipality is far within the constitutional debt limit, it may be determined to be for the interest of the public health to temporarily permit the sewage to go into the streams. However, all permits are limited, usually from one to three years. Philadelphia has five years within which to devise a comprehensive plan for the interception of its many sewer outlets and for the perfection of plans for improved disposal.

The penalty for the discharge of sewage from any public sewer system into any of the waters of the State, without a duly issued permit, where such is necessary, is $500 and a further penalty of $50 per day for each day the offense is maintained.

All individuals, private corporations and companies, that at the time of the passage of the act, were discharging sewage into any of the waters of the State, may continue such discharges unless the Commissioner of Health orders a discontinuance; but the Commissioner is not empowered to permit new sewer outlets owned by individuals, private corporations or companies.

A private corporation, duly chartered by the State and to whom local authorities have granted a franchise for the construction, operation and maintenance of a public sewer system, is considered to be classed with the municipal corporation to the extent that plans must be filed and extensions approved.

The law would be a half measure only if it did not afford

protection to the people who must continue to drink waters taken from sewage polluted sources. Sweeping outbreaks of typhoid are imminent though not probable in many parts of the State, and so it will be while foci of infection exist. It behooves those who travel about to exercise care in the water they drink. Thousands of human lives will be sacrificed before preventive works shall have been adequately installed everywhere. The "Purity Water Act" aims to help.

Every municipal and private corporation, company and individual supplying or authorized to supply water to the public within the State must file a certified copy of plans of the water works and a description of the source with the Commissioner of Health and thereafter no additional source shall be used, or water works constructed, or extended, or new systems installed without application to and a written permit from the Commissioner of Health under penalty of $500 and $50 per day for each day that the works are in operation contrary to the provisions of the act.

The courts are beginning to recognize that it is possible and practicable, barring accidents, careless operation and negligent maintenance and faulty design, for a sewage polluted water to be filtered and rendered safe for drinking. The consumer who purchases a pure and wholesome water is entitled to that kind of an article. That it cannot be obtained in its natural state is immaterial. The Commissioner is charged to consider whether in his opinion the source of supply is prejudicial to public health and the applicant is entitled to a decision in writing. Permits are issued with conditions and stipulations. The jurisdiction of the Commissioner respecting water works in existence prior to April 22nd, 1905, begins only upon extension of such work.

An illustrious son of the commonwealth, a man distinguished in preventive medicine, and a scientist, was sought out and urged to take the Commissionership. Reluctant to accept the great office, knowing its exactions, he has bestowed all his gifts and energy and time, day and night, to the organiza-

tion of the Department and the administration of the law. Taking his work seriously, others have been inspired to do likewise as evidenced by the appropriation of over $2,000,000 for general department expenses for two years. I refer to your servant, Dr. Samuel G. Dixon.

Present Condition of Municipal Sewers of Pittsburgh.

BY I. CHARLES PALMER,*
Non-member.

It is proposed in this paper to briefly present a few facts concerning the drainage and sewers of the City of Pittsburgh. Natural and efficient drainage is afforded the city by the Allegheny, Monongahela and Ohio rivers, the flow of which is so large that it carries away an average of about 45,000,000 gallons of sewage daily without noticing the pollution. This fact has led to the adoption of the combined system of sewers exclusively for Pittsburgh.

The city is practically bounded on the North, South and West by these three rivers which are separated by a rough broken topography, a condition which gives rise to many small sewer systems.

In the city proper the ridge line extends along the hump, Fifth avenue, Bedford avenue, across Center avenue to Forbes street and thence along Linden and Brushton avenues, forming water courses towards the Allegheny and Monongahela rivers. The ridge line on the South Side extends along Grandview avenue, Mt. Washington, towards Montooth street, forming natural water courses towards the Monongahela river and Saw Mill Run.

In all there are 53 sewers draining into the Allegheny river, 41 draining into the Monongahela river, one into the Ohio and 12 into Saw Mill Run, making a total of 106 different outlets.

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The section bounded by the Point, Hump, Bedford avenue and Thirty-third street is drained by 32 small parallel sewers ranging in size from 15 to 60 inches in diameter. The most of these were built in the early days of Pittsburgh when the population was small and when the down town portion was a semi-residence district. These residences and three-story office buildings have since given place to solid business blocks and twenty-story office buildings increasing the working population 40 times that which it was when these sewers were designed. Consequently several of these old brick sewers are taxed beyond their capacity and are so broken and worn that in the near future it will be necessary to either make some very extensive repairs or build entirely new systems. Those in the worst condition are on Fifth street, Seventh street, and Eighth street, between the river and Penn avenue. In places the inverts are worn out and washed away to the depth of four feet below the original flow line.

The first outlet of a large system draining into the Allegheny river is on Thirty-third street and is commonly known as the Two-Mile Run system. It drains a territory of 1,800 acres bounded by Fifth, Penn and Shady avenues. The trunk sewer of this system extends along the Pennsylvania Railroad and Thirty-third street, across the Allegheny Valley Railroad to the river. This sewer is a three-ring circular brick sewer with Ligonier block invert. It has a diameter of 99 inches near the mouth and a grade of 1 per cent which gives a capacity of 48,000 cubic feet per minute which is sufficient for the territory drained. Although built in 1888 there has been practically no repairing done on this system.

Adjoining the Two-Mile Run basin is the Forty-eighth street basin bounded by Penn and Stanton avenues and comprising an area of 760 acres. The trunk line of this system extends through the Allegheny cemetery, and on Forty-eighth street to the Allegheny river. It consists of a circular brick sewer with Ligonier block stone invert 65 inches in diameter, laid on a grade of 75 per cent, which gives a sufficient capacity

to carry all of the water from this basin. This sewer was originally built in 1869 and the portion between Harrison street and Butler street rebuilt 1889, changing the depth several feet and the grade to 1 per cent. At the present writing the sewer, although one of the oldest in the city is in fair condition.

Haights Run water shed adjoins the Forty-eighth street water shed and comprises an area of 840 acres, bounded by Stanton, Highland and Penn avenues. The trunk line follows the old ravine of Haights Run between Chislett street and Highland Park to the Allegheny river. It is a five-foot circular brick and stone sewer laid at a grade of 1.8 per cent, which gives a capacity of 18,000 cubic feet per minute.

The characteristic topography of Pittsburgh, rough, deep, narrow ravines is especially prominent in this section. Hence the time of concentration of storm water is very much less than in some of the other basins.

East of the Haights Run basin we have the Negley Run basin, comprising an area of 2,548 acres. This basin, the second largest in the city at the present writing, is bounded by North Highland, Shady, Linden and Penn avenues which encloses a comparatively level territory. The trunk line of the Negley Run system extends along the Beechwood Boulevard from Silver Lake to the Allegheny river and varies in size from a six-foot circular brick and stone sewer at Silver Lake to a nine-foot circular brick and stone sewer at the Allegheny river. The grade of this nine-foot portion is 0.75 per cent which gives a capacity of 56,800 cubic feet per minute.

Unfortunately this sewer which was built in 1887 is already taxed far beyond its capacity, while a large portion of the territory depending upon this outlet is undeveloped.

At a point called Rock Bend, near the intersection of Frankstown avenue and Beechwood Boulevard the sewer has burst several times in the past five years and caused considerable expense to the city. The chief cause of the trouble at this point is due to a 36-inch circular brick branch sewer entering the five-foot sewer on a very steep grade and consequently at

a very high velocity which checks the flow and causes the water to back up in the five-foot sewer to a sufficient head to burst the sewer. The manhole at this intersection furnishes a spout for the water which has often been seen to shoot 25 feet into the air.

The three-foot branch was built to give relief to a section of 197 acres commonly known as the Belmar Plan, or a part of the Twenty-first and Thirty-seventh wards. The section should rightly be drained into the Nine-Mile Run, a fact which was the intention of the Engineer who designed the Negley Run sewer. However, this branch which was a necessity has been rather expensive. A break of 60 feet last summer above the intersection of the three-foot branch was repaired at a cost of $500. The cost of repairs, due to the overtaxing of this trunk line sewer at this point amounts to $5,000, a sum which will be increased almost annually until the Nine-Mine Run sewer is built, and this section of 197 acres drained into its natural water course.

The proposed Nine-Mile Run sewer will extend through the Forty-first and Thirty-seventh wards, Wilkinsburg, and back into the city beyond Wilkinsburg to the Monongahela river opposite Homestead. It will drain an area of 4,360 acres, 2,650 of which are in Wilkinsburg, Edgewood and Swissvale.

The sewer is badly needed and is being considered by the State Board of Health who will likely authorize its construction in the near future.

The Hazelwood district is drained by trunk sewers on Genesta street and Second avenue which meet at the intersection of said streets and continue on Genesta street, Lytle street and Tecumseh street to the Monongahela river. The Second avenue branch of this system has been overtaxed for several years causing considerable damage to property by flooding cellars. Relief to this trouble, designed by the Engineer in charge and recently completed, is afforded by building a three and four foot brick sewer on Tecumseh street, intercepting the Second avenue sewer at Tecumseh street and the trunk sewer

at the intersection of Lytle and Tecumseh street. This gives the Second avenue sewer immediate and permanent relief.

A relief to the Genesta street sewer as recommended by the Engineer, is to build an overflow on Lytle street intercepting the old trunk sewer so as to carry three-fourth of the storm water into a three-foot concrete sewer built by Jones & Laughlin Co. through their private property for this purpose, while the house drainage, under ordinary flow, will be permitted to drain into the old Tecumseh street sewer. This sewer was built in 1894 and is in good condition.

The Four-Mile Run system drains 3,315 acres, the largest area within the city at the present writing. The crest line of this system extends along Fifth, Shady and Hazelwood avenues. The Jones & Laughlin Company built a 12-foot culvert through their private property and the Baltimore & Ohio Railroad Company built an 8-foot 6-inch culvert under their tracks as outlets for this basin. The city connected these culverts with a nine-foot brick and stone sewer, and designed the Four-Mile Run system with an outlet at the Baltimore & Ohio Railroad of an 8-foot 6-inch circular brick and stone sewer at a 4 per cent grade which gives a capacity of 55,600 cubic feet per minute to drain an area of 3,000 acres. The capacity compared with the area gives an average of 12 cubic feet per minute per acre while that of the Two-Mile Run is 27 cubic feet per minute per acre and the Negley Run 20½ cubic feet per minute per acre.

This Four-Mile Run trunk sewer although designed at the late date of 1897, and although it drains Schenley Park, the capacity is by far too small for the future development of that section of this city.

A small system giving some trouble at present writing is the Cunliff's Run sewer draining an area of 228 acres bounded by Wilmot street, Fifth avenue and Coltart street. It consists of a 24-inch pipe sewer laid from Coltart street in the ravine to Wilmot street and a three-foot circular brick sewer at a 2 per cent grade from Wilmot street to the Monongahela

river. It was built 1886. Since then the hollow above the 24-inch pipe has been filled into a depth of 35 to 100 feet which has evidently crushed the pipe in several places and caused the water to back into the cellars on Coltart street.

As the Bureau of Highways & Sewers desired to give some relief it was suggested by the Engineer to sink a shaft at a point where the evidence of a break was most prominent.

A shaft 35 feet long and four feet wide was sunk to a depth of 25 feet, when the water became so bothersome that the Engineer advised stopping work. In the meantime surface indications showed several breaks between the shaft and Coltart street; facts which warranted ceasing of work and the construction of a three-foot relief sewer on Coltart street. This was recommended by the Engineer April 1st, and accepted May 25th. The Bureau of Highways & Sewers in the meantime having spent at least $3,000. endeavoring to give temporary relief.

The condition of the Soho Run sewer is similar to the Cunliff Run in respect to the large fill above the sewer. Although there is no evidence of breaks, this sewer is entirely too small.

This system drains an area of 500 acres bounded by Kirkpatrick street, Centre avenue and Soho street. The old portion of the Soho Run sewer from Wyandotte street to Tustin street is abandoned while the portion from Tustin street to the Monongahela river, which was built in 1874, is in good condition. This latter part is an eight-foot culvert-shaped sewer with brick crown and stone sides and invert. The trunk line of the system is a five-foot circular brick sewer laid on Brady street at a grade of 11 per cent, and intercepts the old sewer above Tustin street. About 100 feet below this intersection a break occurred last summer in the brick and stone sewer. This break which washed out a hole 35x50 feet and four feet below the grade of the invert was repaired with concrete. The water during construction was carried across the break by

means of a wooden flume 42 inches wide by 18 inches deep and 60 feet long.

Three heavy rain storms arose during the construction of the work and washed the flume into the river, which was twice lost and once recovered. At this break endangered a pier of the Twenty-second street bridge the work was rushed night and day. The total cost of this work was $4,556.

The next large system draining into the Monongahela river is the Fifth avenue and Try street system. The trunk line of this system is a 5-foot 3-inch brick sewer from Shingiss street to Washington avenue built in 1873, a 6-foot 2-inch brick and stone sewer from Shingiss street to Second avenue, a 6-foot brick and stone culvert from Second avenue to the Baltimore & Ohio Railroad built in 1869, and a rubble masonry culvert built by the Baltimore & Ohio Railroad Company, under their tracks to the Monongahela river. Recently a break occurred under the Baltimore & Ohio Railroad tracks at this point washing about 2,000 cubic yards of embankment into the river.

This sewer has been over-taxed for years and in many places worn out. Between Elm and Dinwiddie streets the invert of this sewer is entirely worn and washed away to a depth of four feet below the original flow line. At other points inspection can only be made with great risk and difficulty. A break at Shingiss street in 1905 cost $10,000. for repairs and several thousand dollars damage.

A relief recommended by the Engineer is to intercept the Fifth avenue sewer at Van Braam street, with a five-foot sewer, and thence continue on Van Braam street to Forbes street, and thence by a tunnel under the bluff and Baltimore & Ohio Railroad to the river. The estimated cost of this proposed relief is $38,000.

Two of the largest systems on the South Side are the South Twenty-seventh and Carson streets sewer, draining into the Monongahela river and the Washington avenue sewer draining into Saw Mill Run.

The Carson street sewer, which was built about 20 years ago, had caused considerable damage by flooding the cellars on South Twenty-seventh street. To relieve this trouble a four and five-foot concrete sewer was built last year on South Twenty-fifth street and Carson street, and a brick overflow at the intersection of South Twenty-seventh street and Carson street so as to carry seven thirty-fifths (7-35) of the storm water into the Jones & Laughlin sewer which drains through their property to the Monongahela river.

The Washington avenue sewer is a six (6) foot circular brick sewer with a grade of 3.4 per cent. It drains the territory between Mt. Washington and Montooth Borough (now Forty-second ward). It was built in 1901 and has sufficient capacity for the territory drained.

Many of the branch sewers have been designed too small for the territory drained, a fact which causes several relief sewers to be built annually. In 1906 relief sewers were built on Euclid avenue from Margaretta to Baum street on Thirty-sixth street, from Smallman street to the Allegheny river, and on Carson and South Twenty-fifth streets, from South Twenty-seventh street to the Monongahela river, at a total cost of $77,900. This year relief sewers are being constructed on Aiken avenue from Rebecca street, and from Howe street to the Pennsylvania Railroad, on Atlantic avenue from Craig street to Neville street, and on Tecumseh street from Second avenue to Lytle street, the total cost of which will be approximately $25,000.

The cost of brick sewers compared with concrete sewers in Pittsburgh is approximately the same. However, if conditions are favorable to the use of machinery in handling the material, a concrete sewer is cheaper for sizes above forty-eight (48) inches in diameter.

The trunk sewers and branches spoken of constitute about 210 miles of sewers in the City of Pittsburgh which were constructed at a total cost of about $6,650,000.

The city is constructing sewers at the rate of five to twenty

miles per year. This year to date we are authorized to build nine miles of sewers, a number which will likely be increased to 20 miles before the year expires.

When the State Board of Health deems it necessary for the health of the community to order the sewage of the city to be disposed of by some sewage disposal process in accordance with an act of the General Assembly April, 1905, the city will be compelled to build a complete sanitary sewer system.

Some of the branch sewers in the residence district without drop connections can be reconnected and used as sanitary sewers. The question of diverting the storm water from certain sewers to the natural water courses and using these sewers for the sanitary system will not likely be considered on account of the damage which the storm water would do to private property. However, many of the branches which are insufficient to carry the storm water at present may be used as sanitary sewers and a new storm water sewer designed for the section considered.

The sanitary system can be designed so as to carry the sewage by gravity to six or eight central points or outlets, instead of 106, the number of the combined system. Without going into details in this paper the writer wishes to remark that practically all of the sewage, with the possible exception of that which drains into Saw Mill Run will have to be pumped to suitable locations for sewage disposal plants.

The writer figures that the total length of sewers to be constructed for a sanitary sewer system for the City of Pittsburgh would be 195 miles and would cost approximately $8,000,000. This amount, however, does not include the cost of pumping installations or sewage disposal plants.

Although there is no agitation for a sanitary sewage system within the city at present, and no objection from the State Board of Health to the combined system carrying the sewage into the rivers, the building of the subway and the reconstruction of the down town sewers would bring the problem before the public immediately.

DISCUSSION.

The President: We have with us this evening a member of the Advisory Board of the State Department of Health, Dr. Adolph Koenig.

Dr. Koenig: Mr. Chairman and Members of the Engineers' Society: I have little to say in addition to what you have heard from Mr. Snow on the subject of the proposed improvement in the sewage system of the State. I would, however, like to bespeak your good will, if not your support, in favor of the efforts of the Commissioner of Health towards establishing this new sanitary era for Pennsylvania.

You are already aware of the fact that, before the enactment of these laws, Pennsylvania was practically among the States at the foot of the list, from a sanitary point of view—and especially so from the point of view of vital statistics, in spite of the proud position that the State occupies with regard to other sciences. Now, then, when you consider the condition that prevailed before this and the ideal conditions which your Commissioner of Health intends to establish, you will necessarily recognize that there will be some objection to his work. That the commercial interests that have flourished under this old system will suffer more or less, at least some of them, there is no doubt, but the State must consider the greatest good for the greatest number, and that, I am thoroughly convinced, is the policy of the Commissioner of Health.

The changes in the manner of governing the pollution of rivers and streams, in my opinion, are evolutionary; and I am sure that the Commissioner of Health will not be peremptory, but that a complete change will come and must come, I am sure, but that it will partake of the nature, more or less, of an evolutionary process. And I am sure that the members of this society can do a great deal towards establishing this work on a sound basis. I am sure you will recognize that if some manufacturing concern, for instance, were to pour poison into the streams, let us say arsenic, that carried in its train as many

victims as do the micro-organisms that are annually thrown into the streams, that pollution would stop instantaneously. The people at large look upon disease more or less as a visitation of Providence—do not recognize that disease can be prevented by sanitary measures, and hence are loath to take active steps. I am sure that under the effective work that our Commissioner of Health has instituted Pennsylvania will soon be in the forefront of all the States in matters of general sanitation, to the great good of its citizens.

The President: We would be very glad to hear from Dr. Edwards, Superintendent of the local Bureau of Health.

Dr. James F. Edwards: I am very much interested in the discussion to-night. I think there is no other community; certainly not in this portion of the United States, to which the question of sewage disposal is so important as it is to Pittsburgh. There is probably no large community in the world that is suffering at the present time so greatly from the effects of sewage pollution. I might make the statement that Pittsburgh probably has had the longest continuous period of suffering from sewage pollution. We have had what constitutes practically an epidemic of typhoid in this city since as far back as '73. It is appalling, I think, when you look back over it. We have statistics in the Bureau of Health from the year '73, and there has been a high rate of typhoid fever since that time, at times going very high and at other times going lower, but always very much higher than the average of American cities. There are other streams that are more polluted, probably, than the Allegheny river; we will admit that; but there are very few cities where there are not filtration plants in existence for the purpose of purifying the water. Some streams, for instanec, the Merrimac river, or the Passaic river, in New Jersey, may be more polluted; but when the water supply taken from those streams is filtered, the result of the taking of the water from that polluted source is not so apparent.

Now, it seems to me, before Pittsburgh can consistently

demand that municipalities or boroughs along the river properly dispose of their sewage, it should set the example itself, and it is for this reason that I think this subject is so timely to-night.

The matter of sewage disposal has for some time been taken up in connection with the proposed new sewer down the Nine Mile Run district, of which Mr. Palmer spoke to-night. The Nine Mile Run district comprises a large part of the Thirty-seventh, Forty-first and the Twenty-second wards. The natural course of that drainage is down Nine Mile Run, and, as Mr. Palmer says, part of it is taken into the already over-crowded Negley Run sewer. Some time ago, the Commissioner of Health, Dr. Dixon, took the matter up of the various boroughs, Wilkinsburg, Swissvale and Edgewood, joining with Pittsburgh to project a new sewer system down Nine Mile Run, and considering at the same time the installation of a sewage disposal plant. It has been said by engineers that the topography of that valley is such as to make it admirably suited for a sewage disposal plant. And the matter has been taken up by a committee of Councils and by another prominent body in the city; and I believe the time is not far distant when we will have a sewage disposal plant, which will practically be an experimental one, in that district, preliminary to a proper disposal of the sewage of the whole city.

W. G. Wilkins: I understood Mr. Palmer to say that there was no movement towards sewage disposal in the City of Pittsburgh. This is true so far as the City government is concerned, but the Chamber of Commerce has recognized the importance of the subject, and has appointed a committee, of which I am the chairman, to investigate the subject of sewage disposal with special reference to this city, with the idea of helping to educate the citizens as to the necessity of doing something in the line of sewage disposal. The committee hopes to have the report ready in a short time.

Mr. Webber:* Mr. Chairman and Members of the Society: I often think that probably we are to blame for a great

* Chairman Filtration Committee of Councils.

deal of the illness that has been caused throughout the city. We speak of these things at our meetings, we know what ought to be done, but just as soon as we leave we forget all about what we have been talking of and fail to get the people educated or to get them so excited that they will act. The only way to accomplish anything is by getting the people excited and by getting them to work. Two or three societies may go to work and discuss the health and the welfare of the public, but if they keep it within their own society there is nothing accomplished.

It has taken a long time to get down to filtered water. In the last fifteen years, rapid progress has been made by you gentlemen in the filtration of water. We today are building a filtration plant that is about as fine a filtration plant as there is in the United States. And not only that—there will be others built that probably will be improvements upon the present filtration plant we are building now. They have completed the smoke consumers, they have gone to work now and are clearing up the city of its dust and grime. Now, the next thing for us to do is to get at the sewage disposal. There are two good places that they can start at right away. The Nine Mile Run plan is in the hands of a committee of councils to-day, and Wilkinsburg and Swissvale have not decided as to what they will do with the sewer. If they build a sewer, they will be compelled, of course, to build a disposal plant. That will give us an experimental plant, and then they ought to begin at once to put a disposal plant at Marshalsea. There is a place in which they take typhoid fever patients; they have all kinds of diseases out there, and the sewage is emptied right into Chartiers creek, and carried through a number of small towns. There would be an elegant place for the City of Pittsburgh, at a small expense, to build a disposal plant and find out whether it was practicable or not. If it is, there is no doubt that we can find ways by which we can equip the whole City of Pittsburgh with disposal plants. Just as has been stated, the downtown sewer system here is in bad

shape, and as soon as the subway becomes evident, and the sewers have to be changed, we will have to put in a disposal plant; and then will be an elegant time, and at a very small cost, as the subway people agree to build the sewer system, and the city ought to be willing to take care of the disposal plant. And I think, gentlemen, it will be necessary to get out and educate the people. There is no doubt, as Dr. Koenig said, whenever an epidemic occurs in a city or town, the people think of it as a visitation of Providence that has struck them and has placed upon them something that they had not been looking for. But that is not the case, and you know that it is not the case. Then, why not educate the people and get them to act? They are perfectly willing to follow the lead of those who know what to do and how to do it.

J. P. Leaf: When a farmer hears these subjects discussed and knows for a fact that the cities above Pittsburgh add all their sewage to the rivers, the people of Pittsburgh pump the water out of the rivers and drink it and return it to the rivers; Sewickley, Coraopolis, Freedom, Beaver and the other towns below, turn around and drink this polluted water (some of it treated and some of it not), so on down to East Liverpool, they pump the water direct without treating, and Cincinnati does the same. When we listen to the discussion of bacteria in water and the bacteriain water and the bacteria that we know is necessarily in it, we think that a person who would drink a glass of water from the Ohio river without its being treated, might as well turn a revolver to his head and pull the trigger. Yet those people drink the water year in and year out, and seem to live to a good old age, some of them. I think it is a good thing we are taking up the subject of filtered water supply, taking your water from cribs or driven wells, and in some manner have it filtered through at least three feet of sand. I think it is a good thing also for us to treat our sewage. It ought to be done. I think that while it is undoubtedly a burden on a small town to build a sewer system and water works and a disposal plant, the sewer systems should be separated so

that the treatment of the sewage eventually or soon would be treatment of sewage only. There is no use mixing storm waters and sewage waters and roof waters, because the treatment of sewage waters depends on the number of cubic feet, not on the amount of contamination. So that I think, as engineers, we should design our systems as separate systems; and then, if the system should be so designed and ordinances passed at any time to start purification of the sewage, all roof waters and all waters but such as are absolutely sewage waters, could be turned out of the sanitary sewers. If we took our water by meter, the water works could afford to purify it and filter it; and cutting out all waste would be not only an advantage to the water works or the man who supplies the water, but it would be a great advantage also to the municipality or people that use it. Then turn around and see that nothing goes into your sanitary sewers except what is absolutely house drainage, and there would be a minimum amount of sewage to treat. I believe in case these lines were followed (reasonable lines), almost any town could afford to take their water and filter it and return it to the stream treated.

Willis Whited: The sewage disposal problem in Pittsburgh, as is well known, is very difficult. Some isolated cases, as, for instance, that Nine Mile Run sewer, and possibly the Negley Run sewer, and it is barely possible some of the others, could be treated at a comparatively moderate expense. But the downtown systems are a very difficult problem. I will not attempt to say how it could be done, but the difficulty is to find some place to do it. The amount of land available at a low enough level to make it reasonably practical to get the sewage on to it for purification purposes, and with an area sufficiently large to do the work, is very hard to find; and it is, moreover, very expensive, when it can be found. But it is a problem that must be solved somehow or other, and Pittsburghers are not given to falling down on what they really set out to do. Pittsburgh can do it.

Mr. Wilkins: I believe it might be interesting to this

meeting to hear something about what has been done in other cities, and I think Mr. Snow can give us some idea if he will, as to what is being done in Columbus and Baltimore.

Mr. Snow: I can better state what work is being done generally in Pennsylvania under the auspices of the State Department of Health. Mr. Wilkins is probably more fully informed of the present condition of the work at Columbus and at Baltimore. I understand he has recently visited those places and others in quest of facts and information to be used in a forthcoming report on the subject. I should like to hear from Mr. Wilkins.

Relative to Pennsylvania, the city of Reading is building a modern sewage disposal plant comprising septic tanks and sprinkling filters. This will be the first plant erected under the administration of the new Department of Health.

At Wayne, Delaware county, a sewage purification plant comprising septic tanks, roughing filters and sand bed finishers is nearing completion. This work was decreed necessary by the Commissioner of Health.

The Commissioner ordered the discontinuance of the discharge of sewage into the natural water courses at West Chester. Plans for sewage and sewage works were submitted and approved. However, the electors overwhelmingly defeated the question of a bond issue for the purpose, so the matter may have to be settled in the courts.

Of course, sanitary improvements cost money.

Only by statutory ways can money be raised. The State Department may order changes involving large expenditures, and if the order be not wisely conceived, it may fail of its accomplishment because of matters beyond the jurisdiction of the Department. Each case is an independent and separate problem.

Norristown has gone ahead in defiance of State law and constructed a new sewerage system with an outlet into the Schuylkill river. The power of the State to enforce the provisions of Act 182 of 1905 will be tested in this instance. The

constitutionality of the law whereby the Commissioner of Health has power to prevent and remove nuisances and menaces has been upheld by the highest court in the commonwealth.

The city of York built 43 miles of separate sewers during the last three years costing $400,000. That city has been denied the use of this investment until an intercepting sewer and sewage works shall have been built, estimated to cost $400,000. Plans thereof have been approved and the question of funds is to be decided at a special election.

The towns in the Schuylkill valley are about to be ordered to discontinue the discharge of sewage into the streams. Many of the sewers, as at Pottstown, are private sewers and the remedy is a general public sewerage system. Months are required in the working out of the problem. A summary order to take the sewage out of the stream would be most impracticable, so it was decided in the Pottstown case.

The critic, is silly, who condemns conservatism in the administration of State law about stream pollution. The State constitution prohibits a municipal debt in excess of 7 per cent of the total assessed valuation. When a town is about up to its limit of indebtedness, what purpose does an order from the Commissioner of Health to build a sewer system or sewage disposal works really amount to? So frequently the financial ability of a town limits what can be done. There are other local matters which also control in deciding as to what it is practicable to accomplish. No one law could be framed which would hit all cases. The present law is not perfect, but it is broad enough so that under it a great and beneficient work can be done and as rapidly as the people will stand for the changes which all admit are demanded except those selfishly involved. The support of representative citizens to the existing laws is wanted rather than the perfecting of these laws too soon or the enactment of others more drastic.

As I stated in the paper, Philadelphia has been given five years in which to prepare plans for changes. That city has

over 1,000 miles of sewers and discharges 300,000,000 gallons of sewage daily into the Schuylkill and Delaware. So the problem is an enormous one. Some of Philadelphia's sewers contribute to the pollution of its own water supply. In proceeding to improve the quality of the raw river water of the Schuylkill and Delaware above Philadelphia, the State has had to take cognizance of the conditions in that city also.

Pittsburgh cannot reasonably expect the State to campaign against towns whose sewage goes into the streams above Pittsburgh and overlook the fact that Pittsburgh's sewage pollutes the water supply of towns on the Ohio river below. The law is operative for all. However, in the administration of the law it at once becomes apparent to the trained mind accustomed to grappling with large problems, that the successful working out of plans and methods of procedure relative to the sewers and the disposal problem for Pittsburgh must extend over a period of years and require a relatively long time for consummation. This emphasizes the importance of an early comprehensive study.

The Delaware, Susquehanna, Ohio, Allegheny and Monongahela rivers are inter-state streams.

The Governors of New Jersey and Pennsylvania met in 1906 to inaugurate a policy of co-operation and later the proper authorities of the three States of New York, New Jersey and Pennsylvania, met and agreed upon a common policy for the Allegheny, Susquehanna and Delaware rivers. Most of the pollution of the three streams occurs within the territory of Pennsylvania. New Jersey has already enforced the erection of a number of sewage disposal works in the Delaware basin. Trenton is to have five years in which to study her problem. Camden will not have to take up the question sooner than Philadelphia.

Bristol, Pa., is the first town above Philadelphia on the Delaware. Sewerage and disposal works were ordered by the Commissioner. Plans have been submitted and approved,

and the money voted by the citizens. The works will be built this year.

The city of Easton has been given three years in which to provide treatment works. South Bethlehem a similar time. Allentown is considering the problem.

The towns on the Upper Lehigh and Schuylkill are in the coal fields, so also are those along a part of the North Branch of the Susquehanna and some of the tributaries of the main stream. In the Lackawanna river, sometimes the flow is six parts mine drainage to one part upland water. Sewage organisms do not live long in this acid stream, or they are very rapidly precipitated. Tests do not reveal the presence of coli in the river water a few feet down stream below the large sewer outlets of Scranton. In the coal fields of East and West Pennsylvania, the problem of sewage disposal is connected to some degree with the germicidal and disinfecting effect of mine drainage. The Department is considering the question of the sewage disposal of perhaps 25 municipalities in the coal fields with special reference to mine drainage.

Several towns along the Lower Susquehanna and the upper branches have been permitted to discharge into the streams for three years.

Below Pittsburgh, in the Ohio basin, the city of New Castle has in conformity with an order of the Commissioner, submitted plans for sewage disposal works. Greenville, on the Shenango above New Castle, was denied the right to build sewers without disposal works. Plans thereof have since been prepared and approved and construction work is in progress. The plant comprises septic tanks, contact beds and sand filters.

Zelienople, Ellwood City, New Wilmington, West Middlesex, Emsworth, Edgeworth, Osborne and Carrick have been required to prepare plans for purification works.

Washington borough, Washington county, was ordered to abate a nuisance in Chartiers Creek caused by town sewage. The borough adopted and is now building sewage works in

compliance with plans approved by the State Department. The works comprise septic tanks and sprinkling filters.

Glenshaw, East Brady, Ford City, Meadville, Oil City, Titusville, Edinboro, Cambridge Springs, Youngsville, Warren, Johnsonburg, Ligonier, St. Marys, Indiana, Blairsville, Saltsburg, Derry, Versailles, Stoystown and Meyersdale are some of the places above Pittsburgh in the Allegheny and Monongahela basins which have been permitted to extend sewers, provided plans for sewage treatment works be designed within three years.

In a year from now, if all matters pending in the Department are decreed, there will have been ordered the preparation of plans for the treatment of municipal sewage at at least 100 places in the State.

B. M. Hokanson: I would like to ask Mr. Snow if any towns in the State had sewage disposal plants before this act of 1905 was passed?

Mr. Snow: The Altoona intermittent sand filtration plant was the only one of much size excepting the Reading work. The Reading plant had been in existence for years, was not doing good work, and the State condemned it. The Altoona plant has served a good purpose. Any structure may become outgrown. There were a few small plants scattered about in the vicinity of Philadelphia, Harrisburg, Altoona, etc. Some of the State institutions had broad irrigation systems in use. Complaints about the unsanitary condition of the latter system have lately been filed with the Department of Health.

Mr. Hokanson: Is storm water a pollution?

Mr. Snow: Not storm water, free from house drainage. Roof and storm water do not constitute sewage under the Pennsylvania law, and the courts must make this distinction.

However, wash water from yards and streets of a city does render a stream into which it goes, unsafe as a source for drinking water. What constitutes a pollution, covers a very wide range. Some pollution may be subject to regulation and is, therefore, preventable and possibly illegal—other pollution

may not be subject to regulation and is, therefore, unpreventable and possibly legal.

For instance, the epidemic of this winter at Scranton, where over one thousand people were stricken with typhoid fever, was not caused by an infection on the water shed from any known origin. It may have come from passenger coach closets. The railroads extend along the streams supplying the city with water. For 30 years the public supply was safe. The water company had expended large sums of money to safeguard the purity of the water. Yet, suddenly, by accident, the water became polluted and a deadly poison. So in answering the question, "Is storm water a pollution," one might truthfully say yes and no. I think the courts must make a distinction between a preventable and non-preventable pollution. The Commissioner of Health makes such a distinction. Remedies may be applied affecting preventable pollution and protective measures against pollution of unpreventable origin are also practicable, but they constitute a distinct class.

It is not possible to filter all the storm water poured forth from the streets of a city during some cloudburst. It is possible for a small town on the river below to filter the little part of the river volume required for domestic uses in that town.

Mr. Hokanson: I asked Mr. Snow a minute ago in regard to the discharge of storm water. I am very much interested to see that over in Europe they have in several places made such a system that the drain which carries away the house drainage is so designed that it can carry off, say for ten minutes during the first period of rain, the storm water from the streets down in the house drains; then from that time the house drain will be, so to say, full, and the rest will run over in the storm water sewer and that water is then considered clean enough to be discharged into the open stream. I do not know if that has been adopted in any city in the United States. I would like to hear if it has, and if it is required.

Mr. Snow: It is being adopted in the plans for some of the sewers in the State of Pennsylvania.

Mr. Wilkins: The City of Baltimore is now building the largest sewage disposal plant that has been built in the United States up to this time. It is designed for a population of 500,000 people, allowing 150 gallons per capita, or a total capacity of 75,000,000, at a cost of $3,283,250 for the disposal plant alone, but so designed as to allow an extension to be built giving a capacity of 150,000,000 gallons. In addition to this they are building intercepting sewers and pumping stations to count about as much more, or $7,000,000. One remarkable fact concerning the Baltimore plant is that they are spending this large sum, not to protect their water supply, but to prevent the pollution of the oysters in Chesapeake Bay.

The President: We would be glad to hear from Mr. Craig, Chairman of the Street Committee of the Borough of Edgewood.

Mr. O. B. Craig: Mr. Chairman and Gentlemen: In the discussion this evening, Nine Mile Run valley has been mentioned several times. As explained, the Nine Mile Run watershed takes in part of the City of Pittsburgh, the Boroughs of Wilkinsburg and Edgewood, and part of Swissvale. I represent the Borough of Edgewood, and I would like to state what is being done in our borough looking toward sewage treatment. We have at the present time a sewer system which we might call the separate system; that is, our sewer system takes care of the sanitary drainage and the roof drainage only. Our street drainage goes into the natural water courses. We are now disconnecting the roof drainage of our houses and diverting the same into a system of storm sewers. We have some storm sewers in the borough, which we propose to extend, and we eventually will have nothing in our sanitary sewers but sanitary drainage. Our idea in this is to be ready to put in a sewage treatment plant. When the time comes, we will have our sewage so separated that we will have nothing to take care of but the sanitary drainage. This we consider is the first step, the preliminary step, in the adoption of a sewage treatment plant, and we expect, within a very

short time, to start a sewage plant. We have not decided yet what we will adopt, but we have taken the preliminary step in that direction, and we hope that Edgewood will have the distinction of having the first sewage treatment plant in the Pittsburgh district.

Floods and Means of Their Prevention in Our Western Rivers.

BY T. P. ROBERTS,*
Past President.

The damage due to floods throughout the middle and western states vary greatly in amount from year to year, but represent a mean annual loss of many millions of dollars, and this loss must inevitably increase proportionately with the growth of population, the investment of capital in industries, agricultural development, and growth of transportation.

Sufficient is known regarding such damages as to amply warrant the investigation concerning preventive measures which have been presented for the consideration of several of the State legislatures, and which was acted upon in the case of Pennsylvania by an appropriation of $20,000 to be expended upon examinations, surveys and reports.† Even if there be no prospect for a material betterment of the situation in Western Pennsylvania from a proposed system of reservoirs, or levees, along the river banks, knowledge of the facts should be made public so that other measures may be taken for protection against damages done by ice gorges and floods.

The possibilities of storage reservoirs are largely determined by natural conditions, particularly the topography, the presence or absence of swamps or lakes, and the capacity of soils for ground storage.

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* Civil Engineer, U. S. Engineers Office, Pittsburgh, Pa.

† This appropriation was vetoed by Governor Stuart after the adjournment of the Legislature.

According to Mr. Herbert M. Wilson, of the United States Geological Survey, in the May (1907) number of the National Geographical Magazine, the area of unreclaimed swamp land in Pennsylvania is only 300 square miles; New York, 2,500; Ohio, 1,250; Kentucky, 350; Indiana, 1,250; Illinois, 3,500 square miles. Comparing the Ohio valley states with the region of the great lakes, we find for Michigan 7,500 square miles; Wisconsin, 4,500; Minnesota, 6,000, areas of swamps, not including, in Wisconsin and Minnesota hundreds of lakes.

Swamp areas can frequently at small expense be converted into storage reservoirs. The reclaimed swamp lands in some of the Eastern States have much greater areas than the remaining unreclaimed lands, but their utilization would involve a great cost for damages.

The topography includes the contours of valleys, their width from hill to hill, and the slopes of the stream beds, which latter determines the length of ponds maintained by dams of given heights. In general, the creek valleys of Western Pennsylvania are rather narrow, with slope of 5 to 15 feet, or more, per mile, hence higher dams would be required than in some other regions to store the same volume of water.

We have the advantage in Western Pennsylvania of having an extensive area covered with glacial drift, sand and gravel, capable of storing great quantities of rain water and therefore to a much greater area than many are aware of, controling the flood discharge. Thus, for months at a time, during the summer and fall, the Allegheny river doles out to the Ohio from four to five times as much water per unit of area of its watershed as is supplied by the Monongahela valley. Were it not, therefore, for its capacity for ground storage the floods from the Allegheny would be considerably higher, shorter lived, and more disastrous than they are at present. It is fortunate for Pittsburgh that the Monongahela valley with its clay soil and rapid out-put of storm waters is no larger than it is.

Referring to natural reservoirs, Major Chittenden, Corps of Engineers, United States Army, in a very able report on reservoirs in Wyoming and Colorado, published by Act of Congress in 1898, says:

"The most perfect example in the world as to magnitude and completeness of control is that of the St. Lawrence river, the discharge of which is governed by the five great lakes."

Above Niagara Falls the drainage basin is 265,000 square miles, of which 87,400 square miles, or almst one-third, is water surface. If we conceive the case of three inches actual run-off following a storm covering the entire lake basin above Buffalo, the increased depth at the head of the Niagara River would be only about one foot; whereas, with a similar actual run-off from a sudden short-lived flood in the Allegheny and Monongahela, Greater Pittsburgh would be almost entirely destroyed. Not so much by submergence of its business section as by the powerful currents created by a depth of, say 45 feet, under the influence of a slope of about two feet per mile; such as we have in the Allegheny and on the Ohio for some miles below Pittsburgh. The current would doubtless sweep away many buildings and the reaction about fallen structures would undermine others having deeper foundations. Structural steel buildings on rock foundations would alone be safe in such a flood. The possibilities of such a disaster are, however, in the opinion of the writer, extremely remote, as we have no records of great cloudburst storms covering the entire latitude embraced between the heads of the Allegheny and Monongahela rivers, a distance on a North and South line of 240 miles. There is, however, food for serious thought in the fact that in March last a flood, which will later be referred to more particularly, coming from only the Southern half of this watershed, was considerably higher at Pittsburgh than any known before.

Major Chittenden cites the case of Lake Geneva, Switzerland, which in area equals only 8 per cent. of its watershed, and yet the lake,—228 square miles in area,—greatly miti-

gates the floods of the Rhone river nearly down to the City of Lyons, about 90 miles below the outlet of the lake. Thus, in the great flood of 1856, the water entering the lake was 56,000 cubic feet per second, while owing to its contracted outlet the discharge of the lake was only about 11,400 cubic feet per second. This storage effect of reservoir surfaces even when full to overflowing when a great storm occurs, appears to have been overlooked by our early American writers, but is well worth considering in cases where reservoir sites can be found.

As a matter of fact, in the case of small reservoirs, their extra capacity, if it may be so termed, as can be demonstrated from weather records, would often be the sole reliance in restraining floods, so frequently would they be full when the floods came. For this reason, therefore, it would be advisable on such small reservoirs, by means of valves to be able to temporarily stop overflow and cause them to rise a number of feet higher than their normal level. It must be recollected that with out generally narrow valleys, steep declivities of stream beds, and relatively high bottom lands—not much over one-third of the height of the dams, or embankments—can be assumed for the mean depth of the ponds above them. An extra layer of water over the normal level of such ponds would, however, represent a considerably greater percentage of storage for the additional height of dam required to secure same.

The French engineers appointed by the Government, after the disastrous flood of 1856, in Southern France, to investigate the possibilities of restraining them in the future, called attention to the following point, viz: That reservoirs which happened to be full and overflowing in great volume, on some tributaries from local cloudbursts, may be contributory to increase of flood height in case of floods on the main stream, due to a different storm, whereas had there been no storage reservoirs on the first stream its flood waters would have passed out before the flood from tributaries above arrived.

Such an argument points to the advisability of consider-

ing larger reservoirs, capable of storing all the waters of their catchment basins due to the greatest known storms.

The fact cannot be overlooked that the great expanse of reservoirs affords opportunity in this climate for the formation of great quantities of very thick ice. Such ice escaping from reservoirs might, in certain contingencies, add enough to that in the streams below to materially increase damages due to ice gorges. It is certain that unless means are provided to hold the ice back in the reservoirs, great objections would be raised by the communities and navigators below them.

The point here raised is by no means a question for mere academical discussion, but is one that would be threshed out before the courts in damage cases, as occasions would arrive. The difficulties to be encountered in holding back ice in reservoirs are not, however, insuperable. It is merely a question of arrangement of discharge through submerged valves. Discharges over open weirs is not to be thought of, and therefore ample reserve height of dams or embankments forming the reservoirs should be provided for.

Embankments or Levees.

In considering means for restraining floods in river valleys, the advantages and disadvantages of embankments call for careful consideration. The present writer seeks only to present the salient features of the reservoir and embankment systems, not so much to compare their merits as to say something in regard to their engineering limitations.

In some regions there is a choice of plans for restraining floods, although it is true that resort to embankments rather than to reservoirs for such purpose has been almost the universal practice from the earliest periods of which we have authentic records, as illustrated on the Nile, in Japan, in China, Europe, and lastly in the United States.

The embankment method has the distinct advantage that it can be put in practice locally along any portion of a great river valley without awaiting the action of the powers in con-

trol of the headwaters of the streams. Thus the city of Buda Pesth, Hungary, has raised the banks of the Danube river for a number of miles and brought its streets to conform to the new level to obviate the annoyance and losses created by ice gorges damming the river and flooding the business section of the city. Other places on the Danube have done the same. Pittsburgh might profit by the experience of Buda Pesth and bring about the desired result without depending upon surveys and damage questions arising in distant regions, in the settlement of which the local authorities would not be consulted.

While there is no doubt that embankments, by confining the flood discharge to narrower limits, increase the velocity of the descending sheet of water, to that extent increasing its scouring force, engineers are about equally divided in their opinions as to the effect of levees in filling up the river beds, and as to the necessity for raising them from time to time. The literature concerned with this problem has become very voluminous, especially from writers dealing with the improvement of the Mississippi, where there has been expended by several States and the Nation at large over $50,000,000 upon embankments to restrain floods.

It is generally agreed that during the last 100 years the levees along the Po river, Italy, have been much more frequently overflowed than during the preceding 100 years, and this in the face of the fact that along some parts of the Po valley the embankments are fully six feet higher than they were 200 years ago. Some of the Italian engineers are now discouraging further work of raising the embankments because of the increase in the extent of damages in cases of breaks in them. As one writer says, the damages are now about equal to the benefits from the embankments.

It is also generally agreed that necessity exists for raising the embankments along the Rhone and Loire rivers, in France, and along the Theiss river, in Hungary. It must not be taken for granted because of the necessity for raising embankments that the floods in recent times in Europe have a greater volume

of discharge than during earlier periods. This is the favorite assumption of the friends of forest preservation in whose good work the river engineers heartily join. The engineer cannot, however, close his eyes to the fact that hundreds of years ago gauge records of French and German rivers, upon some of which there are no levees, show if anything a decline of maximum flood heights, comparing early periods with later periods of equal length, or in America, where negative results were shown, comparing the past half with the first half, periods of equal number of years.

The writer elucidated this branch of the subject in a paper read before this Society a number of years ago,* and later extended it for a paper published by the American Forestry Asosociation. The statistics of the European river flood records were chiefly compiled by the German engineer, Gustave Wex, and embraced the Rhine, 1770-1835; Elbe, 1728-1869; the Vistula, 1809-1878; Danube at Vienna, 1826-1874; Danube at Orsova, 1840-1871; Oder, 1778-1835. Herrich, a German engineer, compiled the flood records of the Seine river from 1615 to 1850. In none of these records is there any evidence to show that floods are more frequent or higher in later than in former periods. Herrich says the theories of the forestry men "are not entertained by the most competent students of the subject."

Sir Vernon Harcourt, the eminent English river hydraulic engineer and author, is responsible for the statement that there are streams from the highlands in Japan which hundreds of years ago were embanked to prevent the overflow of the lowlands. In the course of time the Japanese found it necessary to raise the embankments and have kept on doing so until in some cases the beds of the streams are now forty feet higher than the level of the adjoining plains† Harcourt adds: "They serve as a warning against the extensive raising of embankments to counteract the silting up of a river."

Harcourt neglected to state the slopes and range of

* Vol. II. pp, 285-313. †Ency. Brit, Vol. XX. p. 573.

heights and discharges of the Japanese rivers, and therefore, even if we concede his statements to be based on reliable information his warning may not be given the attention which it possibly deserves.

That the Mississippi below Cairo is filling up its bed, thus causing a gradual increase in its flood heights, is probably true, notwithstanding the assertions to the contrary of some able, but not fully informed, engineers. The river when first observed by white men was flowing between natural levees on a mound of its own creation, the crest of the levees being from 10 to 20 feet, or more, higher than the swamps several miles distant from the main stream, which received the overflow discharge. The swamps parallel the Mississippi for hundreds of miles. So it has been from the beginning, the silting up of its bed being constantly in excess of the scouring force. If the reverse were true, there would have been no mound or parallel embankments formed along its course, and the bottom land would have had an inclination towards the river rather than presenting a downward slope away from it, as at present. That the raising of the natural embankments a few feet more, artificially, has caused the great river to cease silting up its bed, is a statement which is not accepted as capable of being proved by any records of soundings, so far as made public, taking the river as a whole and discarding certain records above and below crevasses.

About Pittsburgh it is mostly standing, or back, water which floods our streets, the addition of which to the river, in case the flooded area were filled to a higher level, would not perceptibly increase the height or velocity of the main stream, or tend to silting up the river beds. The same remark applies generally to the upper Ohio, Monongahela and Allegheny rivers, where the bottoms are narrow and covered during floods to a shallow depth only. There are exceptional places, however, where the banks are low and traversed sometimes by strong currents where it would be inadvisable to contract the stream.

There are places both on the Allegheny and Ohio rivers where it would be beneficial to remove high shore and island bars, and in some cases to remove islands to afford greater uniformity to the sectional discharge area of the rivers.

Man's work, in the construction of bridges with numerous piers, encroachments on the banks, badly placed tipples and abutments, creating eddies below them, conspired to materially increase the height of the recent great flood in the vicinity of Pittsburgh. That flood 30 miles below Pittsburgh, on the Ohio, or at the same distance above the city, both on the Allegheny and Monongahela rivers, was not up to preceding flood records, while at Pittsburgh it overcapped the highest preceding flood by about two feet.

Artificial obstructions which rise from the river bed, and built to flood heights as they usually are, by creating great eddies, reduce the mean flood velocities, and are, in the writer's opinion, more effective in increasing flood heights than low dams across the river, which, after being submerged to a considerable depth, have but little visible effect in disturbing the even flow of the rivers in very high floods.

A pile of shavings at a barrel factory, thrown out over the bank of the Monongahela river several years ago deflected the current across the river with such force as to undermine the opposite shore, causing the banks to cave for hundreds of feet, destroying a small railroad bridge and necessitating a large expenditure in pile work and revetment of the river bank. This case is cited to show how an apparently slight cause may, sometimes, by diverting the currents of a river, effect great damage. Such diversions of the current result sometimes in shore eddies below the obstruction in which deposits are made many times larger in cubical contents than the artificial obstruction primarily responsible for their formation.

Local Conditions.

As early as 1849 the distinguished engineer, Colonel Charles Ellet, at the time stationed at Wheeling, West Vir-

ginia, building railroads and suspension bridges, turned his attention to the improvement of the Ohio river. He determined the fact from ten years' daily gauge readings of the river at Wheeling that there was even in the driest years sufficient water passing that point, which, if stored in reservoirs, would not only restrain floods but would afford a depth of not less than six feet all the year around in the unobstructed river. His extensive writings on this subject were published by the Smithsonian Institution and attracted great attention. By 1856 his views had been adopted by many engineers and others, and a large appropriation for surveys of reservoir sites was being urged in Congress. About this time, Mr. W. Milnor Roberts, C. E., of consideable experience in canal and river improvement in Pennsylvania and elsewhere and an advocate of locks and dams for the Ohio, prepared an extensive pamphlet which was published by the Franklin Institute, controverting Colonel Ellet's theories. The chief feature of Mr. Roberts' paper was a discussion of the financial impracticability of obtaining sites for the enormously large reservoirs proposed by Ellet and others, and from a patient study of Ellet's own data attempted to prove that on certain occasions the reservoirs would be full at the very time it was desired that they should be empty. Mr. Roberts' paper was influential in defeating the bill in Congress. The pamphlets and other publications of the period referred to, contain much useful data which might interest students of storage reservoirs.

The present advocates of storage reservoirs are not, however, contemplating the improvement of navigation of the Ohio as part of their proposed plans, excepting incidentally, and on a much smaller scale than advocated by Col. Ellet, who was brave enough to propose to curb the floods of the Missouri and Mississippi rivers, as well as those at Pittsburgh and Wheeling, on the Ohio, by means of great storage reservoirs.

The following table of river gauge readings and rainfall records at various stations along the Ohio, Allegheny and Mo-

nongahela rivers, covering the periods of the recent unprecedented flood at Pittsburgh, are presented as being worthy of record in the proceedings of the Society for future reference.

When the rain commenced on March 13th there were from three to four inches of freshly fallen snow covering the Monongahela and Allegheny valleys, which added probably one-half of an inch to the precipitation which should be taken into account at all stations. The area of the Allegheny valley above Pittsburgh is about 11,500 square miles; of the Monongahela, 7,600, making for the Ohio at Pittsburgh, 19,100 square miles.

It would appear from a study of the table that a great rainstorm from the west traversed Southwestern Pennsylvania. On the 12th and up to 8 o'clock of the 13th, the precipitation in excess of one inch, or more, included the Allegheny basin up to and embracing the Mahoning and Kiskiminetas tributaries, that is to say, the country 50 miles north of Pittsburgh, thence eastward to the Allegheny mountains. It included practically all of the Monongahela valley. This storm was followed by another still more violent, commencing late on the 13th and was practically over before 8 o'clock a. m. of the 14th. Information of its possible effects could not be made public until the 8 o'clock a. m. reports were in, at which time the storm, being a local one, the flood had reached Pittsburgh, rising only about 4½ feet more to 8 o'clock a. m. of the 15th.

Without hourly reports during the night of the 13th no one could have predicted the stage reached by the flood in advance of the arrival of the flood itself.

The northern limit of one inch, or more, rainfall during the second storm passed north of Wheeling, a few miles south of Pittsburgh, thence trending north of east towards Blairsville, striking the mountains north of Johnstown. It included about half of the Kiskiminetas valley and all of the Monongahela basin, the greatest precipitation occurring along the Youghiogheny valley and the Monongahela above McKeesport to Fairmont. The total precipitation at Lock No. 4, 20

Rainfall and river gauge records covering period of flood of March 15, 1907, from 8:00 A. M. daily weather service records of a nnmber of stations above and below Pittsburgh, from March 12th to 17th, inclusive.

"R" indicates river rising. "F" indicates river falling. "T" indicates Trace.

STATIONS	DANGER LINE FT.	12 RAIN IN.	12 RIVER FT.	13 RAIN IN.	13 RIVER FT.	14 RAIN IN.	14 RIVER FT.	15 RAIN IN.	15 RIVER FT.	16 RAIN IN.	16 RIVER FT.	17 RAIN IN.	17 RIVER FT.
Warren. Pa.........	14	.01	1.4	.12	R 1.6	.70	R 3.5	T	R 6.2	.00	F 6.0	.00	R 6.5
Franklin, Pa.........	15	.10	4.1	.34	R 4.3	.46	R 8.0	.00	F 8.4	.10	R 8.8	.00	F 8.2
Clarion, Pa..........	10	.04	2.8	.62	R 3.5	.54	R 8.0	T	F 8.5	.00	F 6.9	T	F 6.5
Parker, Pa...........	20	.04	*.....	.80	* 5.5	.74	* 10.0	.00	F 7.5	.00	F 6.5	.00	F 6.0
Johnstown, Pa......	7	.01	2.5	1.24	R 9.4	1.44	R 18.0	.00	F 9.0	.00	F 6.5	.00	F 5.8
Saltsburg, Pa.......	6	.04	1.3	1.28	R 5.0	.94	R 18.4	.12	F 13.4	.00	F 6.0	.00	F 5.0
Freeport, Pa.........	20	.04	5.0	1.85	R 9.7	.92	R 22.4	.00	F 24.6	.00	F 16.5	.00	F 15.0
Confluence, Pa......	10	T	2.2	1.35	R 11.0	1.80	R 17.2	.02	F 11.4	.00	F 7.0	.00	F 5.0
West Newton, Pa..	23	.20	......	1.00	R 7.9	1.84	R 26.3	.30	F 21.9	.00	F 10.5	.00	F 7.6
Weston, W. Va....	18	.00	0.7	.58	R 1.1	1.12	F 8.9	.04	F 4.5	.00	F 3.0	.00	F 2.2
Fairmont, W. Va..	25	.06	19.8	1.86	R 23.0	1.22	F 24.5	.02	F 22.2	.00	F 19.0	......	....
Rowlesburg, W. Va.	14	.04	5.0	1.46	R 8.4	1.12	F 8.2	.20	F 7.6	.00	F 5.0	.00	F 4.2
Greensboro, Pa.....	18	.08	14.1	1.34	R 18.7	1.90	R 27.2	.12	F 21.0	.00	F 14.2	.00	F 11.2
Lock No. 4, Pa.....	28	.40	19.2	1.40	R 21.0	2.20	R 37.4	.02	F 35.0	.00	F 22.6	.00	F 15.5
Pittsburgh, Pa......	22	.06	9.8	1.52	R 12.7	.86	R 31.1	T	F 35.8	.00	F 22.8	.00	F 15.7
Beaver, Pa...........	27	.14	13.0	1.74	R 17.9	......	....	.00	§ 47.1	.00	F 37.8	.00	F 25 8
Wheeling, W. Va..	36	.04	9.5	1.00	R 17.5	1.20	R 37.9	.00	R 47.8	.00	F 48.9	.00	F 38.0
Parkersburg. W. Va	36	.14	12 2	1.66	R 18.0	1.38	R 37.0	.00	R 48.1	.00	R 51.4	.00	F 50.9
Pt. Pleasant, W. Va.	39	.00	18.4	1.42	R 22.7	......	....	.00	R 46.4	.00	R 52.4	.....	....
Portsmouth, O......	50	.14	24.9	......	....	1.16	R 39.5	.00	R 52.2	.00	R 58.6	......	....
Cincinnati, O..	50	.82	27.3	3.58	R 41.0	2.80	R 50.3	.00	R 54.1	.00	R 57.6	.00	R 60.0

* Closed by ice,

§ About maximum stage.

miles across the country south of Pittsburgh, including the melted snow, was 4.1 inches. It can be said that the basins of the Kiskiminetas, the Youghiogheny and the Monongahela, forming not quite half the catchmen basin at Pittsburgh, contributed perhaps nine-tenths of the water, making the greatest flood ever known to have occurred at Pittsburgh.

It is pertinent to inquire what storage reservoirs could have done to minimize the effect of such a flood.

The "danger line" at Pittsburgh is at a stage of 22 feet on the Market street gauge, below which freshets are supposed to pass without appreciable damage. During the March flood the river remained above the danger line 56 hours, on March 15th being 12.8 feet above it. According to official gaugings of the Ohio river below McKees Rocks, at a 23-foot stage, the discharge of the river is about 230,000 cubic feet per second. At about the maximum height of the flood on March 15th the discharge was found to be 439,000 cubic feet per second, the difference in the discharge between a 23 and 35 foot stage being 209,000 cubic feet per second. Assuming that about one-half of this difference, or, say, 100,000 cubic feet per second, for 56 hours, would represent the volume of water which was desired to provide for in storage reservoirs, it would represent a volume which would fill a reservoir covering about 23,000 acres, or about 36 square miles, to the depth of 20 feet.

The question arises: are there sufficient sites for reservoirs of adequate capacity along the upper Kiskiminetas, Youghiogheny and Monongaheal valleys to have retained such a volume of water? If the reservoirs had been in existence, would they have been available for use at the time of the late flood?

The first question can be answered definitely only after a careful examination of the country, in which labor the excellent topographical maps published by the United States Geological Survey, so far as such survey extends, would prove of great value in determining storage capacity of reservoirs in specific cases.

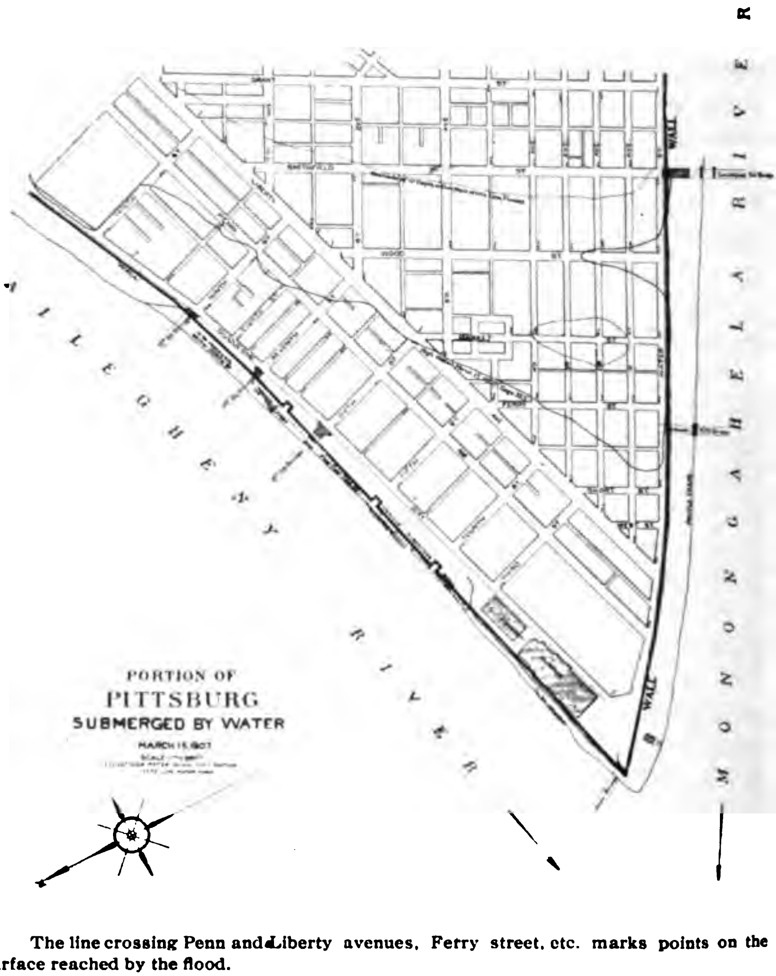
An examination may show for us what was discovered in France; where the engineers after making elaborate surveys following the flood of 1856, reported that reservoirs *could* be built to hold back flood waters to almost any desired extent; but submitted the question whether considering the value of lands permanently ruined by submergence in their construction; damages to railways, mines, etc., such a vast first cost, and large annual maintenance expense was warranted for the purpose of saving flood damages of infrequent occurrence in the valleys below.

The construction of a sea wall and the raising of the streets of Galveston, Texas, shows what is possible for a community neither rich nor populous when actuated by a common impulse and under the leadership of men possessed with indomitable courage. "Ajax defying the lightning" should have a place on the escutcheon of the famous gulf city.

The mere suggestion of raising the river banks and streets of the business part of Pittsburgh above the flood level affords no adequate conception of what else should be done to secure immunity from flood damages. Thus something should be done to reduce to a minimum the infiltration of water from the river through the subsoil, which frequently fills, or partly fills, cellars and basements of buildings remote from the river, and which does much damage to goods stored therein. The extent of such losses, in many instances, are suppressed in the interest of real estate and rental values.

The compartive ease with which certain deep basements excavated through loam and sand to the underlying gravel have been kept pumped out during rises indicates that percolation from the river is not very rapid, although other places may be found where it would be much greater than that observed at the points referred to.

To reduce such percolation to a minimum the writer would suggest the digging of a trench 10 to 12 feet, or more, deep along the outer lines of Duquesne way and Water street, then to proceed as follows:



The line crossing Penn and Liberty avenues, Ferry street, etc. marks points on the surface reached by the flood.

The line nearly paralleling Smithfield street marks the limits where basements of ten feet depth would have had water in them.

Market street, between First and Fourth avenues, is high, being 12 feet above the flood of March 15th.

1st: Through pipes inserted in holes at frequent intervals in the bottom of the trench, grout the subsoil, forcing it with pumps where necessary, varying the consistency and composition of the grout, as circumstances dictated.

2nd: Construct in the trench a concrete wall, ultimately to be carried up to the flood level, as filling proceeded.

3rd: On the inside of the concrete wall, at, say about elevation 18 feet on the river gauge, construct a drain in the trench and connect the same with the sewers at the ends of the streets.

4th: Construct covered pits at street ends, placing in them reliable pumps to be kept in constant readiness to pump the sewers into the river when river gauge indicated eighteen feet. The heavy rains fortunately appear to be over by the times the floods reach Pittsburgh, hence the raising of storm waters does not promise to add much to the duties expected of the pumps* It is supposed, of course, that valves, accessible from the pump pits, would be so placed at the river end of sewers to prevent back water from the river entering them. It certainly should be as much the duty of the municipality to protect its citizens from damages resulting from floods as from fires.

Electric motors, kept ordinarily in warehouses, should be placed in position when needed to operate the pumps, obtaining their power from the nearest wires having the requisite current.

Material for filling streets should be clean river gravel and sand, cheaply dredged from the river, cheaply and rapidly unlodad by machinery from boats and distributed by tram cars operated by electric powers.

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* During the March flood $\frac{88}{100}$ of an inch of rainfall occurred on the night of the 13th at Pittsburgh, after the river was above the danger line. so that pumping from the sewers would have been necessary. The maximum precipitation was $\frac{18}{100}$ inch for one hour. The drainage area below Grant and Eleventh streeets to the junction of the rivers is about 210 acres. To have drained this area at ifs maximum discharge of rain water would have required only about seven pumps equal to a duty of about 2,500 gallons per minute against a head of 12 to 14 feet. Probably not less than 15 pumps of varying capacity would be installed at street ends—within the prescribed limits—so that the care of this exceptional quantity of rainfall at a critical time would not have been a serious matter.

It might be found preferable to drive a line of sheet piles in places in the bottom of the trench rather than to place dependence upon grouting. The durability of piles in our soils above elevation of low water, whether they be of wood or steel, is questionable, so that as a dernier resort, where infiltration from considerable depth in great volume is to be feared, it would be best to carry the concrete wall to the required depth to intercept it. Of course, it is not claimed that thin concrete walls, as ordinarily built, are watertight. In this case even cracks from shrinkage, or from unequal settlement of the walls, unless very large, can be neglected, it being proposed only to reduce percolation from the river to a reasonable minimum. Absolute prevention of such percolation would increase the cost of plans to an unreasonable amount.

It is improbable that a strong flow of water will be met in the deep underlying gravel beyond the capacity of portable pumps, judging by experience with large coffer dams, covering several acres in the rivers about Pittsburgh. It should be recollected in this connection that it is not proposed to pump water from below level of 18 feet on the river gauge, so that during the recent flood the maximum lift would have been 17½ feet. Basements below this prescribed limit would have to be pumped at owners' expense, but the pumps would be called upon to work against a greatly reduced inflow owing to the reduction of head made possible by the public pumps on the river banks, which pumps, during the late flood, would have been in service 56 hours.

An investigation might show no necessity for raising streets and buildings, excepting along Penn avenue and Duquesne way below Sixth street to Fourth street, thence via Ferry street to the Monongahela river. Some exceptionally low places along Duquesne way above Sixth street should also be raised.

To avoid the raising of any streets or buildings it has been suggested that the wall along Duquesne way should be pro-

vided with watertight gateways, affording entrance to the wharf, except when closed to hold back the floods.

Pittsburgh can well afford the best plan. Opposition to the raising of buildings arises, doubtless, in many cases from exaggerated notions of the cost of doing such work, which, for brick and stone structures raised vertically a few inches, or a few feet, as the case might require, would be small, while no steel structures, unless it be the one at the northeast corner of Penn avenue and Fifth street, need be raised. Real estate now in low ground would be greatly enhanced in value by being raised.

Finally the city might consider another plan which would consist of a vertical wall starting at the abutment of the Sixth street bridge, a few feet inshore of its river face, thence carried on a straight line outside the Exposition building, ending against the abutment of the old Union bridge, several feet back of the river face. This wall should rest on piles, tightly sheeted on its front line below low-water level.

The removal of the material outside of such a wall to a depth of ten feet below harbor pool level, especially along the Exposition building, would increase the capacity of the Allegheny river for discharging its flood waters. At several points along the wall hoists, or elevators, for raising wagons and teams should be provided, teams to drive from the elevators to a floating sectional wharfboat against which steamers could land at any place along the wall. In the presence of floating ice a special boat stationed below the Sixth street bridge could be used to deflect the ice and thus protect the craft below. This plan would accomplish results as follows:

1st: Complete stoppage of infiltration of water at flood stage.

2nd: Make a presentable esplanade or embankment susceptible of ornamentation.

3rd: Abolish the sloping wharf which at present affords a place for the deposition of mud and filth brought by the floods.

4th: Betterment of facilities for handling river commerce which, in view of the improvement of the Ohio river, affording an outlet to the Gulf of Mexico and to the Panama Canal, and to the Great Lakes when a canal is built connecting them with the Ohio river.

Other walls within the limits of Greater Pittsburgh would, of course, be needed in a general scheme of protection, but reference to them is unnecessary at this time.

The Proportioning of Steel Railway Bridge Members.

BY HENRY S. PRICHARD,*
Non-Member.

The calculated stresses in bridge members are at best only approximations, but the assumptions on which they are based and the principles involved in their determination are so definite and firmly established by usage that there is little room for dispute in any ordinary case as to the amount of the calculated primary stress. In proportioning bridge members, however, there is much difference of opinion in regard to many important points. A number of the fundamental questions involved in proportioning steel railway bridge members are discussed in this article under the following captions:

Available Strength of Structural Steel.
Safe Working Stresses.
Rules for Designing Compression Members.
Provisions for Possible Increase in Live Loads.
Provision for the Dynamic Effect of the Live Load.

Available Strength of Structural Steel.

It is possible that improvements in the processes of manufacturing steel, or in the fabrication of structural parts and structures therefrom, may make it practicable and desirable to

* Beaver, Pa.

use steel of higher strength in the future than at present, but under existing conditions, for ordinary structural purposes, it requires steel of comparatively low ultimate strength to be readily workable and to stand without serious injury the processes of fabrication, the handling during erection and the shocks it may receive in service.

As a basis for designing steel bridges, the critical question in regard to strength is **"What is the greatest permanent or indefinitely repeated load which structural steel will sustain without undue deformation?"**

Structural steel which has not previously been subjected to an external load is to some extent in a state of internal strain, in consequence of which, when it is first tested by a gradually increasing load, it usually displays slight imperfections in elasticity and acquires a slight permanent set before, and sometimes long before, there is any considerable loss in elasticity. Eventually under a gradually increasing load, the point commonly known as the elastic limit, is reached where the low rate of change in length characteristic of steel strained within its elastic limit, suddenly changes to the high rate which results from the flow of the metal after the destruction of its elastic properties. This point is well described by the term "yield point," which has to some extent replaced the older term, "elastic limit." Some seventy years ago imperfections in the elasticity of cast iron were observed by Mr. Eaton Hodgkinson, who found that a stress, however small, was sufficient to produce a set, or permanent change of form, and he was led to conclude that "the maxim of loading bodies within the elastic limit has no foundation in nature."* Prof. James Thompson, in an article in the Cambridge and Dublin Mathematical Journal for November, 1848, attributed the fact observed by Hodgkinson to high internal strains and further stated: "It appears to me that the defect which he has shown to occur even with very slight strains, exists only when the strain is applied for the first time, or in other words, that if a

* Report of the British Association for 1837, page 362.

beam has already been subjected to a considerable strain, it may again be subject to any smaller strain in the same direction without taking a permanent set." This remarkable prediction has been verified by subsequent experiments, the most notable of which are those by Prof. Johann Bauschinger, published in his "Communication," 1886, and described by Prof. Edgar Marburg* as follows:

"By means of his remarkable measuring apparatus—sensitive to the ten-thousandth part of a millimeter (about $\frac{1}{250000}$ in,) Bauschinger not only confirmed the correctness of Hooke's classic law, but he showed that within the elastic limit the permanent set, as well as the total elongation remained constant, both after the lapse of time and under repeated applications of the original load.

"Accordingly, after an initial stress, of a given magnitude within the elastic, has been once developed, the material is afterward perfectly elastic up to the limit of that stress."

The results of some of Bauschinger's experiments on the resistance of various kinds of metal to repeated strains in comparison with the ultimate strength under one application of the load, likewise in comparison with alternate strains of the same intensity in both directions, were given by Mr. C.C. Schneider† as shown in Table No. 1, with the caution that the values are in pounds per square inch, and are approximate only.

The steel termed "Ingot Iron" in Table No. 1 is the quality used for ordinary structural purposes, and its strength under repeated stresses is given as 34,140 lbs., which is 55 per cent. of its ultimate strength under one application of the load. It was discovered by Prof. R. H. Thurston and announced to the Am. Soc. of C. E., in November, 1873, and it has been shown by many investigators since, that iron and steel strained beyond the yield point and subsequently allowed to rest will have their elastic strength correspondingly raised. It has also been shown by Wöhler's famous experiments that iron and steel, when over-strained, will develop a permanent

* Trans. Am. Soc. C. E., Vol. XLI, page 226.
† Trans. Am. Soc. C. E., Vol. XLI, page 173.

TABLE NO. 1

	Ultimate Strength	Repeated Strains	Alternate Strains
1. Wrought Iron	49,500	28,450	25,170
2. Ingot Iron	62,000	34,140	28.160
3. Material not specified	57,600	31,290	28,160
4. Material not specified	57,180	34,130	32,140
5. Thomas Steel	87,050	42,670	42,670
6. Rail Steel	84,480	39,820	39,820
7. Boiler Plate, Ingot Iron	57,600	34,130	27,000
8. Material not specified	47,650	31,290	22,750

strength in excess of the yield point, if part of the load is permanent and part continuously repeated, and on this showing Launhardt and others devised formulas for unit stresses in which the permissible stress varies with the varying relations between the maximum and minimum stresses. These formulas were once very much in vogue and are yet used, but they, or any formulas in which the permanent strength developed by straining structural iron or steel beyond the yield point, is used as a basis for design, are radically in error, for the reason that at the yield point the deformation is so great that before the strength of the steel of which bridge members are composed could be increased by over-straining, most members would be elongated or compressed and injured to such an extent that they would be incapable of properly performing their functions in the bridge; thereby jeopardizing adjacent members. In illustration of this fact, the elongation of certain eyebars tested at the Waterman Arsenal have been compiled and given in Table No. 2.

In all of the tests cited in Table No. 2, except test 4134, it is probable that the ultimate strength was unnaturally high, and that therefore the "ratio of yield point to ultimate" was unnaturally low, as the load was temporarily released near the ultimate, and in three cases rests, varying from five to

TABLE NO. 2

Elongations of Eye Bars, in inches, at the Yield Point and at various loads per square inch above and below the Yield Point; compiled from Watertown Arsenal Report 1886—Vol. 2, pages 1573-98.

Test No.	Stress at Yield Point Pounds	Ratio of Yield Point to Ultimate	ELONGATIONS IN INCHES						
			At 1000 lbs. below Yield Point	At Yield Point	At loads exceeding Yield Point by				
					1000 lbs	2000 lbs	3000 lbs	4000 lbs	5000 lbs
4134	37000	57%	0.59	1.08	2.59	2.68	2.88	3.85	4.09
4135	38000	55%	0.41	0.85	2.14	3.10	3.40	3.75	4.08
4136	39000	55%	0.57	1.07	2.35	3.30	3.61	4.02	4.44
4137	37000	52%	0.42	0.95	2.07	2.32	3.31	3.45	3.80
4138	39000	54%	0.65	1.60	2.25	2.82	3.20	3.56	3.99
4139	37000	52%	0.46	1.00	2.08	2.73	3.50	3.70	3.93

Elongations in 260 inches recorded to left of heavy line.

Elongations from center to center of pin holes, 25′ 8″, recorded to right of heavy line.

twelve minutes, were allowed before applying the ultimate load. In specimen tests the stress at the yield point is usually 60 per cent. or more of the ultimate stress.

Some tests made by Prof. R. H. Thurston* have a bearing on the strength of wrought iron and inferentially on steel under permanent loads. He "suspended a number of iron wires, under carefully adjusted and attached static loads, ranging, by differences of 5 per cent., from 95 per cent. to 65 per cent. of their ascertained breaking loads under the ordinary tests, where the testing machine produces prompt rupture by steadily augmented tension, unintermitted to the point of rupture. Two qualities of the same material were used; the one being set up hard-drawn as it came from the wire block, the other having been carefully annealed after the last reduction. The results of this experiment were as given in Table No. 3 (Thurston's No. 11).

*Trans. Am. Soc. of C. E., Vol. XLI, page 516.

TABLE No. 3. (Thurston's No. 11.)
Endurance of Iron Under Dead Loads.

PER CENT. MAXIMUM STATIC LOAD.	TIME UNDER LOAD BEFORE FRACTURE.	
	HARD, UNANNEALED WIRE.	SOFT, ANNEALED WIRE
95	8 days.	3 minutes.
90	35 days.	5 "
85	Unnoted, but 1 or 2 years	261 days.
80	91 days.	266 "
75	Unbroken after several years.	17 "
70	Same results.	455 "
65	" "	455 " (probable jar)

Some of these wires were still unbroken in 1898, after fifteen years' loading; but, some slight oxidation setting in, the further prosecution of the experiment promises less certain deductions:

A consideration of the results of Bauschinger's experiments on "ingot iron" under repeated stresses, as given in Table No. 1, and of the stress and elongation at the yield point of full sized eyebars, as given in Table No. 2, together with the Thurston endurance tests given in Table No. 3, leads to the conclusion that the available strength of structural steel liable to tension only is not far from 55 per cent. of the ultimate tensile strength under one application of the load. As the yield points for structural steel in tension and compression do not differ greatly, it would seem to be a reasonable assumption that the greatest available strength of structural steel liable to compression only is about 55 per cent. of its ultimate tensile strength. In a bridge member, any strength in excess of about 55 per cent. of the ultimate tensile strength can only be attained after greatly elongating or compressing and injuring it, and is liable to be only temporary. These conclusions apply also to the flanges of plate girders, but not to pins, for the

reason that at the point of maximum bending moment in pins, the metal at the top and bottom can be considerably overstrained under repeated loadings and have its strength increased thereby without causing undue deformation.

For steel subject to alternate tension and compression, the tests which have been made do not lead to a very definite or satisfactory conclusion. According to Bauschinger's experiments, as given in Table No. 1, the resistance of wrought iron to alternate stresses is slightly over 50 per cent., and ingot iron 45 per cent. of its ultimate strength. In Wöhler's experiments, however, the resistance of wrought iron to alternate stresses is only 36 per cent.

Some tests on a steel bar at the Watertown Arsenal showed that "A permanent deformation of one-half of one per cent. in either tension or compression entirely destroyed the perfect elasticity of the material under the opposite kind of stress."* This loss of elasticity is only temporary as was shown at the Watertown Arsenal by tests, on test pieces cut from an overstrained steel bar, after a rest of three years and three months. These tests showed high elastic limits in both tension and compression.** A similar result was obtained by tests on test pieces cut from a steel bar, one month and seven days after it was broken in test 4137 previously referred to.***

The foregoing conclusions regarding the strength of structural steel may be summed up as follows:

The available strength in either tension or compression is about 55 per cent. of the ultimate tensile strength.

Under continuously alternating stresses of equal intensity, the available strength lies within the limits 35-45 per cent. of the ultimate tensile strength.

When long intervals of rest occur the strength is not impaired by occasional alternating stresses.

* Prof. J. B. Johnson's Materials of Construction, page 522.

** Prof. J. B. Johnson's Materials of Construction, page 512.

*** Watertown Arsenal Report, 1886, part 2, p. 1589-95.

Safe Working Stresses.

If the assumption on which structural steel bridges are designed were complete and absolutely correct, the available strength of the steel exactly known, and the possibilities of mistakes, defects and deterioration eliminated, there would be no necessity for a factor or margin of safety, but the greatest available strength of structural steel could be safely used in designing bridges. The fact that these ideal conditions are not realized, and that, in consequence, a factor or margin of safety is used in designing structures, has frequently been cited as a reproach to engineers by paraphrasing "the factor of safety" as "a factor of ignorance." Engineers may be lacking in some knowledge which they might reasonably be expected to possess, but when the importance of safety and the possibility of defects, deterioration and increase in loading are considered, the relation which the stresses used in designing safe structures bear to the real strength of iron and steel, is an indication of knowledge and sagacity rather than ignorance.

The possibilities for which a margin of safety should be provided may be classified as defects, deterioration and contingencies. In this classification, defects include errors in the assumptions from which the stresses have been determined, mistakes in calculations, defects in the material, and blunders and injury during fabrication and erection; deterioration includes loss in section or quality of the material from rust or otherwise; and contingencies include any occurrence the possibility of which is too remote to include in the assumptions, or the magnitude or effect of which is greater than it would be reasonable to assume at the time the design is made. Among these contingencies is the possibility of increase in the train load; an occurrence which, in the past, has probably been more potent in determining the lives of railway bridges, than all other causes combined.

The same margin of safety is not needed by all the members of a bridge, but owing to special defects; such for instance as the defect in the assumption that live loads are sta-

tically applied, or special liability to defects, deterioration or contingencies, some members need a greater margin of safety than others; hence it is best to make the provision for safety, in part specific, and in part general.

The usual and most convenient method of making general provision for safety of structural steel bridges, is by using standard working stresses which are less than the greatest available strength of the steel.

In general, the most rational and convenient method of making specific provisions for safety, is not to vary the working stresses, but to make certain additions to the calculated stresses, or in some cases to require certain details of design, quality of steel, or method of manufacture.

When wise specific provisions for safety are adopted, there is, of course, need for less general provision, and higher working stresses can be adopted.

The margin of safety resulting from the general and specific provisions made in designing a new bridge should be greater than that required as a condition of safety in an existing bridge. Economy requires that a new bridge shall have a fairly long life, during which there is liability to deterioration and to some increase in the live load. This liability would not have to be given the same weight in deciding whether an existing bridge is safe under existing conditions, as in designing a new bridge. An existing bridge can be condemned on account of possible future deterioration or increase in loading when the deterioration or increase takes place. There is no sure line between absolute safety and unsafety, as any structure, however well designed and carefully built, is liable to failure and serious injury, and the line between reasonable safety and unsafety has to be fixed somewhat arbitrarily. Such being the case it is natural and reasonable, that, even apart from the possibilities of future deterioration in quality and increase in loading, engineers should prefer and decide on greater safety for new bridges than they require in existing ones.

The "available strength of structural steel," as shown

under this caption, is about 55 per cent. of the ultimate tensile strength. In accordance with general practice, steel made by the open-hearth process is recommended, with usual requirements as to composition and ductility and an ultimate strength of 60,000 lbs. per square inch. As manufacturers require the privilege of some variation in the ultimate strength, steel with an ultimate as low as 55,000 lbs. is liable to be furnished when 60,000 lbs. is specified. On this basis the available strength should not be considered as more than the 55 per cent. of 55,000 lbs., or about 30,000 lbs. per square inch.

It is difficult to get engineers to commit themselves as to the greatest working stress they permit in an existing bridge before condemning it, and their public recommendations in this regard are liable to be more conservative than their practice. It is probable that in some cases, under great provocation, undue risks are taken, but the general experience with iron and steel railway bridges under the trying condition of ever increasing loads, justifies a fairly close approach to the limit above cited.

From some acquaintance with old bridges, from papers presented before the Am. Soc. of C. E.* and from occasional admissions of other engineers, there is little doubt that the calculated stresses in tension frequently exceed 20,000 lbs. per square inch and that few railroad bridge engineers after making proper allowance for impact, would in actual practice condemn a structural steel bridge, in good condition, simply on account of calculated tensile stresses of 20,000 lbs. intensity.

In view of the foregoing facts it may be considered that good practice permits in existing bridges, a working tensile stress of about two-thirds the available strength of structural steel, say 20,000 lbs.

In designing new bridges a much lower working tensile stress should be used. Previous practice and a preference for simple relationships suggest that the working stress should be

* "What Is the Life of an Iron Railway Bridge?" Mr. J. E. Greinor, Trans. Am. Soc. C. E., Vol. XXXIV, p. 294, and "Concerning the Investigation of Overloaded Bridges," Mr. Wilbur J. Watson, Trans. Am. Soc. C. E., Vol. LVII, p. 247.

one-half the greatest available strength or one-fourth the specified ultimate strength, but in view of the specific provision recommended for possible increase in live load, a working stress for tension is recommended which is slightly greater than one-half the greatest available strength. The greatest load per square inch of gross section allowed on compression members should be somewhat less than the allowed stress per square inch of net section in tension members, as it is doubtful whether the rivot shanks, considered as sectional area, have the same efficiency as the metal they replace.

To be on the side of safety the allowance for alternate stresses in members with riveted end connections, should be based on Wohler's experiments on wrought iron instead of Bauschinger's experiments on steel. This will provide sectional areas greater than required for stresses in one direction only in the proportion of 55 to 36 which is an increase of 50 per cent.

Owing to the play in the pin holes, the loads which produce alternate stresses in members with pin ends, are applied with an impact which not only increases the stress, but tends to enlarge the pin holes. The writer has seen pin holes which had been greatly enlarged from this cause. Pin connected members liable to frequent alternations of stress had best be avoided, but if used, should have greater areas than required for similar members with riveted end connections.

Maximum wind stresses occur so seldom in the life time of a bridge, and the intervals between maximum stresses are so great, that it is not necessary to add anything to the area required by the stress in either direction, on account of wind stresses in an opposite direction.

No one speed can be recommended for determing centrifugal force, but it should be specified for each case to suit the speed of passenger trains for short spans and freight trains for long spans. As centrifugal force is actually a component of the live load, it appears logical to consider it as live load and add for dynamic effect.

The foregoing conclusions lead to specific recommendations as follows:

Safe working stresses for tension in main members, 16,000 lbs. per square inch.

Safe loads on compression members, 15,000 lbs. per square inch properly reduced for length.

Members liable to alternate stresses should be proportioned for each kind of stress separately considered, but each kind of stress should be regarded as increased by F per cent of the lesser kind, not including any increase on account of alternate stress from wind. When a member has riveted end connections, F should be 50; when it has pin ends it should be 100.

Centrifugal force should be considered the same as live load and a corresponding addition should be made for dynamic effect.

Rules for Designing Compression Members.

During the last twelve years much attention has been devoted to the analysis of structural members in compression both under ideal conditions and the conditions of practice and many articles of great theoretical excellence have been published, notwithstanding which engineers are yet using formulas founded partly on the results of experiments and partly on false theories. In fact engineers in their practice, with regard to compression members, have profited very little from the increase in theoretical knowledge. This failure to obtain practical benefit from theory has been due partly to the fact that the theoretical column formulas are complicated and difficult to apply, partly to the fact that slight variations in the assumed conditions of practice make great differences in the results given by the formulas, and partly to the fact that considerations of stiffness make it necessary to prohibit long columns and reduce the allowed load on columns of moderate length, regardless of theory.

A good formula for compression members should be simple in its application; it should admit on occasion of allowance for intentional eccentricity or for transverse loading, such as a member's own weight; it should give results agreeing closely with theory for short members and allow loads somewhat less than allowed by theory for members of moderate length; it should provide an ample margin of safety as compared with the results of tests; and, to avoid flimsiness, it should gradually reduce the allowed unit load as the length increases, until it becomes zero at the limiting length. In regard to this last condition most of the formulas in use are quite faulty. What good reason is there for prohibiting the use of a column with an area of twenty square inches and a ratio of length to radius of gyration of 101, and allowing a column with an area of ten square inches and a ratio of 100 to be used to support a load of 86,000 pounds? This inconsistency is not unusual in bridge specifications.

Compression members take their names from their principal stress, but they are always liable to some bending stresses.

Bending stresses in compression members arise from three primary causes and one incidental cause:

Primary causes.

First—Prearranged or intentional eccentricity in the application of the longitudinal load; that is eccentricity that exists by reason of the design of the member and its connections.

Second—Transverse loading, such for instance, as a member's own weight.

Third—Defects in material, fabrication and erection; such as variation in elasticity and sectional area, which may shift the axis from the position assumed, and faulty alignment of the member. These defects exist to some extent in all compression members and by inducing deformation are highly detrimental, except for very short members.

Incidental Cause.

Deformation—This cause of bending stresses is unimportant for very short compression members, but its importance increases with the length of the member and is so great for long members that they will fail from this cause under loads which will produce only very small stresses from direct compression and primary bending moment.

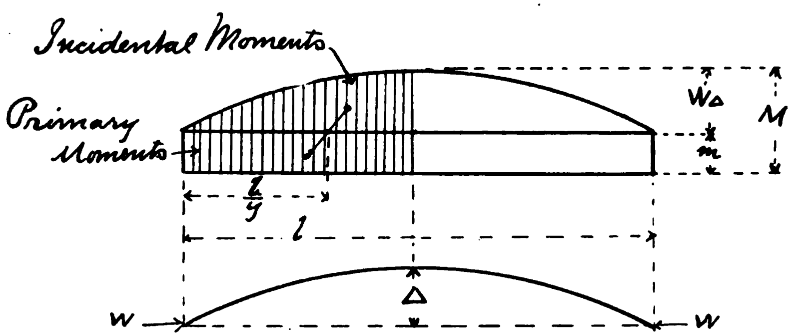


Figure 1

To determine the area required by a member with frictionless hinged ends and constant cross section under the combined action of direct compression and primary bending stress from eccentricity or symmetrical transverse bending.

Let W=the load producing the direct compression.
" F=the greatest stress per square inch.
" C=the area required for direct compression.

$$C=\frac{W}{F} \qquad \text{(1)}$$

Let m=the primary bending moment.
" r=the radius of gyration in inches.
" v=the distance from the neutral axis to the extreme fibre on the concave side.
" B=the area required for the primary bending moment.

$$B=\frac{m\,v}{F\,r^2}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Let Δ =the deflection.
" D=the area required for the incidental bending moment.

$$D=B\frac{W\,\Delta}{m}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Let l=the length of the member in inches.
" E=the modulus of elasticity.
" $\frac{l}{y}$=the distance from the end of the member to the center of gravity of the moment diagram for half the member.
" $x\ (W\Delta+m)\ l$=the half area of the moment diagram.
" A=the total area required for the cross section of the member.

$$\Delta=\frac{x\ (W\Delta+\mathrm{m})\ l^2}{y\ Ar^2\ E}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

For convenience this equation can be put in the form

$$\Delta=\frac{Zm\ (l/r)^2}{A\ \pi^2\ E}+\frac{ZW\Delta(l/r)^2}{A\ \pi^2\ E}\ldots\ldots(5)$$ in which Z is a variable factor, the value of which depends on the form of the moment

diagram. For a rectangle it is $\frac{\pi^2}{8} = 1.234$, for a parabola $\frac{\pi^2}{9.6} = 1.028$ and for a sinusoid 1.

If the cause of the primary bending moment is eccentricity, the value of Z in the first term of the second member of equation 5 is 1.234 and in the second member it varies within the limits 1.028 and 1. If "m" is large as compared to "$W\Delta$," the curve of deflection approximates a parabola, while if "$W\Delta$" is large as compared to "m" the curve approximates a sinusoid. For practical purposes a sinusoid can be assumed in all cases. On this assumption:

$$\Delta = \frac{Zm + W\Delta}{A} \frac{\left(\frac{l}{r}\right)^2}{\pi^2 E} \quad \ldots\ldots (6)$$

Let $p = \frac{W}{A}$ and $q = \frac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$ which is Euler's formula.

$$\Delta = \frac{m Z}{A\ (q - p)} \quad \ldots\ldots (7)$$

Substituting this value in equation 3.

$$D = B \frac{p}{q - p} Z \quad \ldots\ldots (8)$$

From this equation it is evident that the area is not proportional to the load, but that it grows larger in proportion to the load as the load increases. For this reason it is necessary to introduce a factor of safety, g, as regards the area required for the incidental moment.

$$D = B \frac{gp}{q-gp} Z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

To aid in using equation 9 it is desirable to have a table giving the various values of q for different values of $\frac{l}{r}$

In finding the area required for direct compression, if no allowance were made for defects F should be taken as 15,000 pounds per square inch, as specified under the caption "Safe working stresses," but in preparing table No. 5 the area required for defects was assumed as one-ninth the area required for direct compression and the value of F was taken correspondingly higher; that is 16,667 pounds.

In finding the area required for the incidental bending moment, E was taken as 29,000,000 and g, the factor of safety, as 3. Inasmuch as the unit stress used in proportioning for the direct compression and primary bending moment has a factor of about two, as compared with "the available strength of structural steel," a factor of three may seem higher than necessary in proportioning for the incidental bending moment, but it affects very short columns but little, and longer columns should have a greater factor as they have less temporary strength after the yield point is passed and are more liable to defects in alignment.

The formulas from which Table No. 5 was prepared are based on the assumption of frictionless hinged ends. In tests the friction on pins fixes the ends of centrally loaded columns until a comparatively high load is reached, but it does so by a slender margin which a shock or slight eccentricity may overcome and it is a poor reliance in practice.

In theory the strength of a centrally loaded column with fixed ends is equal to a similar column with frictionless hinged ends of one-half its length, but in practice the other members to which a compression member of a bridge is connected by stiff connections cannot always be relied on to even partially fix its ends, in fact in some cases it may even receive bending moment from the adjacent members. For this reason, in view

TABLE NO. 4

Values of the Modulus of Buckling "q" $= \dfrac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$

E=29 000 000 lbs. per Sq. in.

l—length, in inches. r=radius of gyration, in inches.

l/r	Values of q	l/r	Values of q	l/r	Values of q
2	71,555,000	82	42,567	162	10,906
4	17,889.000	84	40,564	164	10,642
6	7,950.500	86	38,700	166	10,387
8	4,472,200	88	36 960	168	10,141
10	2,862,200	90	35,336	170	9,904
12	1,987.600	92	33,816	172	9,675
14	1,460 300	94	32,393	174	9,454
16	1,118 000	96	31,057	176	9.240
18	883,390	98	29.802	178	9,034
20	715,550	100	28.622	180	8,834
22	591.360	102	27,511	182	8,641
24	496,910	104	26,463	184	8,454
26	423.400	106	25,473	186	8.273
28	365,080	108	24.540	188	8,098
30	318.020	110	23.655	190	7,929
32	279.510	112	22,817	192	7,764
34	247.590	114	22,024	194	7,605
36	220,850	116	21,271	196	7,451
38	198.210	118	20,556	198	7,301
40	178,890	120	19,876	200	7,155
42	162,260	122	19.230	202	7,015
44	147.840	124	18.615	204	6,878
46	135,260	126	18,029	206	6,745
48	124,230	128	17,469	208	6,616
50	114,490	130	16.936	210	6,490
52.	105 850	132	16,427	212	6,368
54	98,155	134	15,940	214	6,250
56	91,269	136	15,475	216	6,135
58	85,083	138	15,029	218	6,023
60	79,506	140	14,603	220	5,914
62	74,459	142	14,195	222	5,808
64	69,878	144	13,803	224	5,704
66	65,707	146	13,427	226	5,604
68	61.899	148	13,067	228	5,506
70	58,412	150	12,721	230	5,411
72	55 212	152	12.388	232	5,318
74	52,268	154	12,068	234	5,227
76	49 553	156	11,761	236	5,139
78	47,045	158	11,465	238	5,053
80	42,722	160	11,180	240	4,969

TABLE No. 5.

Sectional areas required for columns, of various relative lengths, under a load of 33,333 pounds, applied with such varying eccentricities as require certain given areas for intentional primary bending stresses.

AREA REQUIRED FOR		TOTAL AREA REQUIRED										
Direct Compression At 15,000 lbs. Pr. Sq. Inch.	Intentional Primary Bending	$^1/_r = 0$		$^1/_r = 25$		$^1/_r = 50$		$^1/_r = 75$		$^1/_r - 100$		$^1/_r = 25$
		By Rule	By Theory	By Rule	By Theory	By Rule	By Theory	By Rule	By Theory	By Rule	By Theory	By Rule
2.22	0.000	2.22	2.22	2.29	2.25	2.50	2.38	2.96	2.84	4.0	4.03	7.27
2.22	0.222	2 44	2.44	2.52	2.50	2.75	2.72	3.26	3.27	4.4	4.44	8.00
2.22	0.444	2.67	2.67	2.75	2.74	3.00	3.00	3.56	3.62	4.8	4.82	8.73
2.22	1.111	3.33	3.33	3.43	3.44	3.75	3.83	4.41	4.57	6.0	5.81	10.91
2.22	2.222	4.44	4.44	4.58	4.59	5.00	5.07	5.93	5.93	8.0	7.25	14.55
2.22	4.444	6.67	6.67	6.87	6.86	7.50	7.44	8.89	8.42	12.0	9.84	21.82
2.22	6.666	8.89	8.89	9.15	9.00	10.00	9.70	11.85	10.73	16.0	12.30	29.09

To right of heavy line, the results given "by rule" are preferable to those given "by theory," on account of greater stiffness.

of the fact that it adds little to the cost, it is recommended that in designing new bridges no reduction should be made on account of seemingly fixed ends.

The amounts given in Table No. 5, as required "by rule," were determined by the following formula which is recommended for use in practice:

l=the unsupported length of the member in inches.
r=the radius of gyration.
m=the intentional primary bending moment.
v=the distance from center of gravity to extreme fibre on concave side.
W=total longitudinal load in pounds.
A=sectional area in square inches.

$$A = \frac{W}{15000 - \frac{2}{3}\left(\frac{l}{r}\right)^2} + \frac{m\,\frac{v}{r^2}}{15000 - \frac{2}{3}\left(\frac{l}{r}\right)^2} \qquad (10)$$

This equation is also applicable to structural steel columns in buildings, but as the loads are comparatively quiescent and the conditions quite different from those which exist in bridges, it is not usual or necessary to be so conservative as to always assume hinged ends. If the ends are evidently well fixed the denominator of the second member of equation 10 can be changed to $15{,}000 - \frac{3}{8}\left(\frac{l}{r}\right)$

For some purposes it is more convenient to have the formula give the working load per square inch.

Let p=the working load in pounds per square inch.
" b=the compression per square inch from the intentional primary bending moment.

$$p = \frac{W}{A} \text{ and } bA = \frac{mv}{r^2}$$

Substituting these values in equation 10.

$$p = 15000 - b - \frac{2}{3}\left(\frac{l}{r}\right)^2 \qquad (11)$$

In determining the safe strength of a compression member in an existing structure, the value of "p" can be increased by a factor "K," say 25 per cent, and if the ends are evidently well fixed, the fraction $\frac{2}{3}$ can be reduced to $\frac{3}{8}$ on the assumption that the member is as stiff as it would be if it were only three-fourths as long and had frictionless hinged ends.

Provision for Possible Increase in Live Loads.

A well designed railroad bridge, in consequence of its margin of safety, should have a fairly long life even if the conditions of service prove somewhat more severe than those assumed in making the design.

The most economical distribution of the margin of safety is the one, by reason of which, when the time comes for renewing the bridge, every member and detail thereof will be equally unsafe, with no surplus metal anywhere. It may seem at first thought, that the rational way to strive for such a result, is to simply use unit stresses which have a factor of safety, as regards the greatest available strength of the steel, assuming, of course, that proper additions have first been made to the stresses in the various members to allow for the dynamic effect of the live load. For some of the purposes for which a margin of safety is provided this method is a rational one; but for a possible increase in live load it is not economical, nor always safe. In illustration of this statement, consider the stresses in four hypothetical members, as follows:

As designed.

First Member— (Eye bars)	Live and impact................	+ 192,000 lbs.
	Dead	0
	Maximum	+ 192,000 lbs.
	Area at 16,000 lbs.=12 sq. in.	
Second Member— (Eye bars)	Live and impact................	+ 192,000 lbs.
	Dead	+ 192,000 "
	Maximum	+ 384,000 lbs.
	Area at 16,000 lbs.=24 sq. in.	

Safe centrally applied Loads on Columns, in pounds.

Fixed Ends $15000 - \frac{3}{8}\left(\frac{l}{r}\right)^2$ Hinged Ends $15000 - \frac{2}{3}\left(\frac{l}{r}\right)^2$

Fixed Ends l/r	Hinged Ends l/r	Load (pounds)	Fixed Ends l/r	Hinged Ends l/r	Load (pounds)	Fixed Ends l/r	Hinged Ends l/r	Load (pounds)
16.32	12.25	14,900	110.8	83.07	10,400	155.8	116.8	5,900
23.10	17.32	14,800	112.0	83.96	10,300	156.6	117.5	5,800
28.28	21.21	14,700	113.1	84.85	10,200	157.5	118.1	5,700
32.65	24.49	14,600	114.3	85.73	10,100	158.3	118.7	5,600
36.51	27.39	14,500	115.5	86.60	10,000	159.2	119.4	5,500
40.00	30.00	14,400	116.6	87.46	9,900	160.0	120.0	5,400
43.20	32.40	14,300	117.8	88.32	9,800	160.8	120.6	5,300
46.18	34.64	14,200	118.9	89.16	9,700	161.7	121.2	5,200
48.99	36.74	14,100	120 0	90.00	9,600	162.5	121.9	5,100
51.64	38.73	14,000	121.1	90.83	9,500	163.3	122.5	5,000
54.15	40.62	13,900	122.2	91.65	9,400	164.1	123.1	4,900
56.57	42.43	13,800	123.3	92.47	9,300	164.9	123.7	4,800
58.88	44.16	13,700	124.4	93.27	9,200	165.7	124.3	4,700
61.10	45.83	13,600	125.4	94.07	9,100	166.5	124.9	4,600
63.25	47.43	13,500	126.5	94.87	9,000	167.3	125.5	4,500
65.32	48.99	13,400	127.5	95.66	8,900	168.1	126.1	4,400
67.33	50.50	13,300	128.6	96.44	8,800	168.9	126.7	4,300
69.28	51.96	13,200	129.6	97.21	8,700	169.7	127.3	4,200
71.18	53.38	13,100	130.6	97.98	8,600	170.5	127.9	4,100
73.03	54.77	13,000	131.7	98.74	8,500	171.3	128.5	4,000
74.83	56.12	12,900	132.7	99.50	8,400	172.0	129.0	3,900
76.59	57.45	12,800	133.7	100.2	8,300	172.8	129.6	3,800
78.31	58.74	12,700	134.7	101.0	8,200	173.6	130.2	3,700
80.00	60.00	12,600	135.6	101.7	8,100	174.4	130.8	3,600
81.65	61.24	12,500	136.6	102.5	8,000	175.1	131.3	3,500
83.26	62.45	12,400	137.6	103.2	7,900	175.9	131.9	3,400
84.85	63.64	12,300	138.6	103.9	7,800	176.6	132.5	3,300
86.41	64.81	12,200	139.5	104.6	7,700	177.4	133.0	3,200
87.94	65.95	12,100	140.5	105.4	7,600	178.2	133.6	3,100
89.44	67.08	12,000	141.4	106.1	7,500	178.9	134.2	3,000
90.92	68.19	11.900	142.4	106.8	7,400	179.6	134.7	2,900
92.37	69.28	11,800	143.3	107.5	7,300	180.4	135.3	2,800
93.81	70.36	11,700	144.2	108.2	7,200	181.1	135.8	2,700
95.22	71.41	11,600	145.1	108.9	7,100	181.8	136.4	2,600
96.61	72.46	11,500	146.1	109.5	7,000	182.6	136.9	2,500
97.98	73.48	11,400	147.0	110.2	6,900	183.3	137.5	2,400
99.33	74.50	11,300	147.9	110.9	6,800	184.0	138.0	2,300
100.7	75.50	11,200	148.8	111.6	6,700	184.8	138.6	2,200
102.0	76.49	11,100	149.7	112.3	6,600	185.5	139.1	2,100
103.3	77.45	11,000	150.6	112.9	6,500	186.2	139.6	2,000
104.6	78.42	10,900	151.4	113.6	6,400	186.9	140.2	1,900
105.8	79.37	10,800	152.3	114.2	6,300	187.6	140.7	1,800
107.1	80.31	10,700	153.2	114.9	6,200	188.3	141.2	1,700
108.3	81 24	10,600	154.1	115.5	6,100	189.1	141.8	1,600
109.5	82.16	10,500	154.9	116.2	6,000	189.7	142.3	1,500

Third Member—(Counter rod)	Live and impact................	+ 192,000	lbs.
	Dead	— 160,000	"
	Maximum	+ 32,000	lbs.
	Area at 16,000 lbs.= 2 sq. in.		
Fourth Member—(Eye bars)	Live and impact................	± 184,000	lbs.
	Dead	+ 192,000	"
	Maximum	376,000	lbs.
	Area at 16,000 lbs.=12 sq. in.		

With Live Load increased 25 per cent.

First Member—(Eye bars)	Live and impact................	+ 240,000	lbs.
	Dead	0	
	12	+ 240,000	lbs.
	Tension per sq. in..............	20,000	lbs.
Second Member—(Eye bars)	Live and impact................	+ 240,000	lbs.
	Dead	+ 192,000	"
	24	+ 432,000	lbs.
	Tension per sq. in..............	18,000	lbs.
Third Member—(Counter rod)	Live and impact................	+ 240,000	lbs.
	Dead	— 160,000	"
	2	+ 80,000	lbs.
	Tension per sq. in..............	40,000	lbs.
Fourth Member—(Eye bars)	Live and impact................	± 230,000	lbs.
	Dead	+ 192,000	"
	12	+ 422,000	lbs.
		— 38,000	lbs.
	Tension per sq. in..............	18,000	lbs.
	Compression per sq in..........	1,600	lbs.

In the foregoing illustration, assuming 20,000 lbs. as the greatest safe stress, an increase of 25 per cent. in the live load; would strain the 1st member to the limit of safety, would yet leave some surplus strength in the 2nd member, would strain the third member to twice its safe limit and would cause considerable compression in the fourth member, which is designed to resist tension only.

While economical provision for future increase in loading

can not be made nor safe provision assured by simply specifying low unit stresses, special provisions which are economical can be made. Such being the case, the question arises should such special provisions be made, and if so, for what percentage of increase in loading?

In the light of past experience some increase in the live load is a reasonable possibility and the effect of such increase, as illustrated in the four hypothetical cases previously given, makes it advisable to make specific provision therefor. The percentage of increase for which specific provision should be made is a matter of judgment. The loads have seemingly approached fairly close to the limitations imposed by the clearances between the tracks and above the roadbed. Twenty-five years ago 100 per cent. would have been none too large. To-day 50 per cent. is probably ample, except for counter stresses.

If the contingency should arise of some extraordinary load twice as great as the live load for which a bridge was designed, it would not cause a calculated intensity of stress much in excess of the yield point in any of the members liable to one kind of stress only, but counters and other members in which the excessive load produced counter-stresses, might be very much overstrained or strained in a way they were not built to resist, even if the excess in load was much less than above assumed. As it does not require the addition of much metal to the counters and members liable to counter-stresses, to give them as well as the other members of a bridge a factor of two in this regard, it seems wise to do so.

The method of proportioning bridges not only for the specified live load with the specified unit stresses, but also for a 50 per cent. increase in the live load with maximum safe unit stresses (say 25 per cent. greater than those specified) and for a 100 per cent. increase in the load, with unit stresses 100 per cent. greater than those specified, is objectionable in practice for the reason that it necessitates the use of three sets of unit stresses and leaves it a matter of trial to determine which con-

dition of loading is the governing one in proportioning each bridge member. Precisely the same result can be accomplished, using only the specified unit stresses, by making proper additions to the stresses to provide for possible increase in live load. The amounts to be added can be determined as follows:

Let D=the dead load stress.
" L=the static stress from the specific live load.
" I=the addition for dynamic effect of the specified live load; or briefly, impact.
" P=the amount to be added to the live load stresses and impact to provide for possible increase in loading.

When live and dead load stresses are of the same kind—

$$\frac{L+I+D+P}{16{,}000}=\frac{1\tfrac{1}{2}L+1\tfrac{1}{2}I+D}{20{,}000} \qquad (12)$$

$$P=\frac{L+I-D}{5} \qquad (13)$$

When the live and dead load stresses are of opposite kinds—

$$\frac{L+I-D+P}{16{,}000}=\frac{1\tfrac{1}{2}L+1\tfrac{1}{2}I-D}{20{,}000} \text{ or } \frac{2L+2I-D}{32{,}000}, \text{ whichever gives the larger result} \qquad (14)$$

$$P=\frac{L+I+D}{5} \text{ or } \frac{D}{2}, \text{ whichever gives the larger result} \qquad (15)$$

Whatever may be the necessity for provision for increase in loading under present conditions, there is little doubt that had it been made twenty or twenty-five years ago, it would have prolonged the life of many a bridge.

The provision for possible increase in loading, is made chiefly in the stringers, floor beams and light truss members, and even if the increase in loading does not occur the provision

may not be amiss, as an increase in the speed of trains may increase the impact in the members in question, and a little extra metal in the floor system may compensate for deterioration from rust.

Provision for the Dynamic Effect of the Live Load.

The rapid application of the load, the hammering of the counter-weighted driving wheels and the jolting and teetering of the engines and cars produce an effect on bridges from impact and accumulative vibration, the determination of which, even if all the governing conditions were known, is such a complicated problem that it is hopeless to attempt a theoretical solution, but some phases of the problem have been successfully analyzed and the conclusions to which the analyses lead are of assistance in considering the general subject.

The simplest case of impact is that of a load falling on the center of a plain beam or girder.

Let a load P fall from a height h to the center of the top of a girder of uniform section resting on two supports. Let W be the weight of the girder, B the uniformly distributed dead load carried in addition to its own weight, $\triangle$ the deflection due to a static load P, and I the static load equivalent in effect to the impact.

$$\text{Then } I = P \sqrt{\frac{2h}{\triangle\left(1 + \frac{17(W+B)}{35\,P}\right)} + 1} \quad \ldots\ldots\ldots\ldots \quad (16)$$

This equation can be readily derived from those developed in Article 112 of Professor Merrimans' "Mechanics of Materials." It is theoretically correct, within the elastic limit, and can be substantiated by laboratory experiments. The value of $\triangle$ can be determined from the equation.

$$\triangle = \frac{P \times \text{length}^3}{48 \times \text{Modulus of elasticity} \times \text{Moment of Inertia}} \quad \ldots\ldots\ldots\ldots \quad (17)$$

The impact given in the table No. 6 following, has been determined by equations 16 and 17 for rectangular steel beams of various sections and for varying conditions as stated.

TABLE NO. 6

Impact to be added to a static load, *P*, when the load falls from a height, *h*, to the center of certain beams of length, *l*, and weight, *W*, supporting an additional uniformily distributed dead load, *B*.— Determined from equatims 16 and 17.

Case	l	h	BEAM Depth	BEAM Thickness	P (tons)	W	B	W+B	Impact
1	Any	0	Any	Any	Any	Any	Any	Any	P
2	12 ft	½ in	6 in	2 in	$\frac{l}{12}=1$	¼ ton	0	¼ ton	2.95 P
3	"	"	"	4 in	"	½ "	"	½ "	3.86 P
4	"	"	"	8 in	"	1 "	"	1 "	4.93 P
5	"	"	"	2 in	"	¼ "	¼ ton	½ "	2.82 P
6	"	"	"	"	"	¼ "	¾ "	1 "	2.61 P
7	"	"	"	2½ in	"	5/16 "	11/16 "	1 "	2.88 P
8	"	"	12 in	1 in	"	¼ "	0	¼ "	5.64 P
9	"	"	24 in	½ in	"	" "	"	" "	11.10 P
10	"	2 in	6 in	2 in	"	" "	"	" "	5.64 P
11	"	8 in	"	"	"	" "	"	" "	11.10 P
12	24 ft	½ in	$\frac{l}{24}=12$ in	"	$\frac{l}{12}=2$	1 "	"	1 "	2.12 P
13	48 ft	"	$\frac{l}{24}=24$ in	"	$\frac{l}{12}=4$	4 "	"	4 "	1.57 P

A consideration of this table indicates:

First—The well-known fact that a load suddenly applied produces twice the effect of an equal static load. The effect is doubled no matter what the dimensions of the beam or the amount of the dead weight.

Second—That in a general way the impact increases with the depth of the beam and the height from which the load falls and decreases with the length of span.

Third—That when the weight of the beam is large in proportion to the falling load, the percentage of impact is much larger than when the weight of the beam is small in proportion to the falling load. This is contrary to the general belief, but in accord with experience.

Fourth—That the addition of external dead load without any increase in the weight of the beam, causes a slight decrease in the impact. If, however, the weight of the beam is correspondingly increased to carry the increased dead load, the net result may be a slight increase in the impact.

There is a popular belief that dead load is highly beneficial in reducing the effect of impact, a belief which is supposed by many engineers to have a firm theoretical basis, but there is little to justify such a supposition in the thirteen cases given in Table No. 6. However, the conditions which obtain for railway bridges under moving loads are vastly different from the simple cases analyzed. In fact equation (16) should be used with caution, even for the effect of loads falling on beams, as a lack of elasticity in either the falling load or the dead load carried by the beam will result in dissipating a part, and in some cases a large part, of the energy assumed by theory to be spent in straining the beam. It may, therefore, be the case that the dynamic effect of the live load is reduced by the addition of wood and ballast in floors or even by an increase in the weight of other parts of bridges, but the claims made in this regard should be substantiated by experience and tests before they are accepted.

For short spans the rapid application of the engine load and the increase in pressure from the unbalanced portion of the counterweighted driving wheels, are the chief causes of dynamic strains.

If a concentrated load travels over a girder at a very slow speed it will produce the same strain as a static load in successive positions. If it moves at a greater speed, the strain will

be greater than for a static load, and the strain will increase with increased speed till a certain critical speed is reached, depending on the length of the span, deflection, etc., after which it will decrease as the speed increases and will become nil at infinite speed. The problem is a very complicated one and has not been solved by analysis.

Among the experiments made for the British Board in 1848 by James, Willis and Galton was a series on a wrought iron beam 9 ft. long, 1 inch wide and 3 inches deep, which was subjected to a load of 1,778 pounds moving at different velocities, with results as follows:

Velocity in feet per second.	0	15	29	36	43
Deflection in inches	0.29	0.38	0.50	0.62	0.46

In this series of experiments the speed causing the greatest deflection was 36 ft. per second. As the deflection of 0.29 inches correspond to an extreme fibre stress of 32,000 pounds, the stress in all the tests were in excess of the elastic limit and are not, therefore, proportional to the deflections. Comparing the deflections with those of other iron beams strained beyond the elastic limit, it seems likely that the maximum dynamic effect on the beam in question, was about equal to the effect of a 60 per cent. increase in the load statically considered.

As the speed necessary to produce the maximum dynamic effect increases with the span and depth, it is only very short bridges; say something under 25 ft., that are liable to the maximum increase from the rapid application of the engine load.

The revolution of the counterweighted driving wheels of engines, with part of the counterweights unbalanced, produces through the action of centrifugal force, alternate increases and decreases in the pressure, the magnitude of which is proportional to the square of the speed of the train. The increase in pressure in terms of the weight on the drivers has been computed by Prof. Turneaure for speeds of 40 and 50 miles per hour for a number of engines (account was taken

of the fact that the counterweights are 90° apart and the resultant effect obtained) and the results were published in Trans. Am. Soc. Vol. XLI, page 435. From these results the following table (No. 7) has been prepared and extended to include higher speeds for passenger engines.

TABLE NO, 7

Weight Lbs.	Diameter of Drivers Ins.	Stroke Ins.	Weight of Drivers Lbs.	Excess Weight on Each Wheel Lbs.	CENTRIFUGAL FORCE (Percentage of weight on Drivers) Miles per Hour 40	50	60	70	80	90	100
141,000	69	24	50,000	180	13	21	30	40	53	67	83
154,000	62	24	54,000	152	13	21	30	40	53	67	83
146,150	62	24	55,400	179	16	24					
178,200	68	24	64,100	203	12	19	27	37	48	61	75
189,100	62	26	84,500	168	16	24					
170,600	56	26	76,700	155	19	30					

The greatest increase in stress from unbalanced counterweights of driving wheels occurs in spans which are so short that the maximum stress is produced by the drivers of passenger engines.

In applying the principle of increased pressure from counterweights, allowance should be made for increase in dynamic effect from the rapidity of application. For instance, if the weight on drivers is 100%, the increased pressure from counterweights 50%, and the increase in effect from rapidity of application 30%, the total increase over the static stress will be 50+30 (100+50)=95 per cent.

After a span of some 20 odd feet has been reached, the dynamic effect from rapidity of application of load rapidly decreases as the span increases, and the increased pressure from the counterweights becomes smaller in proportion to the live load. On the other hand, the increases and decreases in pressure are repeated at rhythmical intervals, occasionally causing accumulative vibration. The alternate falling and rising of the

engine and cars as they pass from floor-beam to floor-beam over the depressions caused by the deflections of the stringers, likewise occasionally causes accumulative vibration.

When the car length is twice the panel length the impacts from the car trucks are nearly simultaneous, and when the engine has passed over and the load consists only of cars, the impact is proportional to the entire load, whereas the increased pressure from the counterweighted locomotive driving wheels is proportional to the weight on the driving wheels only.

There is a theory that finds some acceptance, that a bridge can be destroyed by the accumulative vibration caused by very small impulses, if only the impulses are repeated often enough and at proper intervals. This theory is, of course, fallacious, as it takes no account of the rapid dissipation of energy in a vibrating structure. After the vibration reaches a certain amplitude, which may multiply the effect of a single impulse many times and yet produce comparatively small stresses, the energy added by each impulse will only suffice to replace the energy dissipated and will not increase the vibration.

Prof. Robinson, in a paper on "Vibration of Bridges,"* classifies the conditions favoring cumulative vibration in railroad bridges as follows:

PRIMARY:

Under suitable train speed:

First—Non-balance of drive-wheels in locomotives as now constructed.

Second—Yielding stringers in bridge floors, with equality of panel and half-car length.

SECONDARY:

a. Vertical vibration of car on its springs.

b. Equality of drive-wheel circumference and panel length of bridge.

c. Excess of non-balance of drivers down at mid-panel.

d. Free pedestal blocks, as on expansion rollers.

* Trans. Am. Soc. Vol. XVI, February, 1887.

e. Fish-shaped trusses, pedestals at neutral line.
f. Absence of parts overreaching banks causing friction.
g. Firm instead of yielding load."

For each condition of loading each bridge has a natural period of vibration. The speed most favorable to cumulative vibration is one which causes the dynamic impulses to occur at intervals harmonizing with the periods of vibration.

Prof. Robinson, in the paper cited, describes tests on "thirteen different bridges of four different railways resulting in one hundred and ninety-three indicator diagrams." These tests, together with the three hundred and fifty-nine described by Prof. Turneaure in a paper entitled "Some experiments on Bridges under moving Loads,"* form a valuable and instructive collection. About one-third of Prof. Turneaure's experi-

*Trans. American Society, C. E. Vol. XLI, p. 410.

TABLE NO. 8

Percentage of Increase in Deflections of Railway Trusses under Moving Loads. Compiled from Prof. Robinson's Experiments by recording for each case the test giving maximum increase.

Reference Number	Span in Feet	Pass. Train		Freight Train		Cars only		Panels		Depth
		Per Cent.	Speed	Per Cent.	Speed	Per Cent.	Speed	No.	Length	
6	128	10	...	11	Abt. 40	19	Abt. 40	16	8′ 0″	15′ 0″
5	128	16	...	...	...	...	...	9	14′ 3″	16′ 6″
2	140	29	...	10	29	30	29	9	15′ 7½″	24′ 0″
11	141	23	...	23	...	50	24	9	15′ 8″	Abt. 24′
10	148	23	41	4	43	21	43	10	14′ 9⅜″	24′ 0″
3	156	21	48	19	Low	...	...	10	15′ 7¼″	24′ 0″
13	156	23	...	...	...	...	...	11	14′ 2¾″	Abt. 24′

ments were on plate girders and two-thirds on eleven truss spans. A synopsis of the important tests; that is, those giving the maximum percentage of increase for each span, is given in Tables Nos. 8 and 9.

The increase of 80 per cent. in the center diagonal of

TABLE NO. 9

Percentages of Increase in Stresses of Railway Trusses under Moving Loads. Compiled from Prof. Turneaures Experiments by recording for each case the test giving maximum increase.

Reference Nunber	Span in Feet	CHORDS						CENTER DIAGONAL OF WEB						PANELS		Depth
		Pass. Train		Freight Train		Cars		Pass. Train		Freight Train		Cars				
		Per Cent.	Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	Per Cent. Speed	No.	Length	
15	104	19	42	23	39	24	28	23	41	38	28	60	28	6	17′ 4″	23′ 0″
18	106	...	...	11	40	32	47	...	...	12	27	46	47	6	17′ 8″	12′ 0″
17	123	16	39	...	...	11	32	21	39	0	32	...	...	6	20′ 7″	27′ 0″
19	126	...	...	11	35	...	...	...	...	9	35	...	...	6	21′ 0″	26′ 6″
16	127	17	47	17	40	25	28	28	45	25	36	80	28	7	18′ 3″	24′ 0″
23	146	...	...	...	...	...	...	25	52	26	37	...	...	9	16′ 3⅜″	24′ 0″
22	147	18	40	18	27	...	...	12	27	18	20	...	...	11	13′ 4½″	21′ 0″
21	147	17	32	14	27	...	...	12	32	13	23	...	...	6	24′ 7″	23′ 0″ to 30′ 0″
13	158	10	40	24	27	33	28	22	40	55	30	...	...	8 1	17′ 9″ 16′ 3″	25′ 0″
14	175	16	44	6	25	...	...	...	...	16	36	...	...	8	21′ 10½″	29′ 0″
20	200	18	24	14	...	...	...	...	...	...	...	...	...	7	28′ 7″	24′ 0″ to 38′ 8″

Bridge No. 16, Prof. Turneaure's Experiments, resulted in a total stress of only 900 lbs. per square inch, and is shown in a subsequent paragraph to be of no value as a criterion for designing bridges. Omitting this case, the Robinson and Turneaure experiments on truss spans over 100 ft. indicate:

First—That the maximum percentage of increase was much greater when the load on the bridge was composed of cars only, than it was when it consisted of a train headed by an engine.

Second—That the percentage of increase bore an intimate relation to the panel length and was decidedly greater for panel lengths approximating one-half the length of an ordinary freight car or the circumference of an ordinary engine driving wheel, than for other lengths.

Third—That the length of the span had no influence on the percentage of increase.

The ratios of vibration are not given in the tables, but they are given in the papers referred to, which papers clearly show that the maximum percentages of increase occur, from accumulative vibration, when the rate of the dynamic impulses harmonizes with the rate of vibration.

The Proceedings of the 6th annual convention of the American Railway Engineering and Maintenance of Way Association contain a report of the committee on Iron and Steel Structures, one portion of which is in regard to Impact and refers to some two thousand tests made on various members of different bridges. As stated in the report, all data in connection with these tests was destroyed in the Baltimore fire, except a few bare results. All these tests were made on bridges on the Baltimore & Ohio Railroad, and in order to obtain slow speed tests the railroad company had all trains on the day these tests were made move across the bridge at a very slow speed, running from 4 to 20 miles per hour. Then on the second day all trains were permitted to run at the regu-

lar speed, which ranged from 40 to 70 miles per hour. The speed was ascertained by using a stop watch; the train moving over a measured distance of about 500 ft., and an automatic drop signal being arranged at the beginning and end of this measured distance. In a general way these experiments show that the impacts or vibrations are not noticeable to any extent for speed under 15 or 20 miles per hour, the diagram being practically a smooth line. As the speed increased beyond 20 miles per hour the vibrations became more and more decided, and at fastest speed we have the sharpest and greatest vibration.

The results of these tests as given below are the minimum and maximum of all tests made on the individual bridges, and are for fast speed. They show the excess due to fast speed and slow speed.

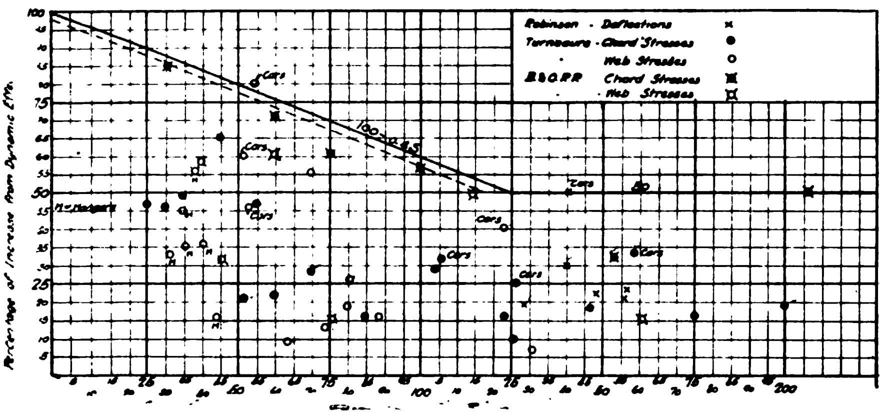
Span or Length of Loading.	Measured Impact Per Cent.
PLATE GIRDERS.	
31 ft. 6 in.	15 to 85
60 ft. 3 in.	36 to 71
75 it. 6 in.	18 to 61
BOTTOM CHORD OF TRUSSES.	
100 ft.	16 to 57
153 ft.	11 to 32
207 ft.	18 to 50
MAIN AND COUNTER TIES OF TRUSSES.	
40 ft.	16 to 58
60 it.	20 to 60
76 ft. 6 in.	9 to 15
114 ft. 9 in.	5 to 49
161 ft.	4 to 15
HANGERS.	
38 ft.	8 to 56
46 ft.	17 to 32

To assist in deducting rules for practice, the cases giving the maximum percentages of increase in the chords and webs were selected, from the before mentioned Robinson, Turneaure and Baltimore & Ohio experiments, and plotted in diagram "*A*" (omitting from consideration those recorded results after

which Prof. Turneaure has placed an interrogation point.) The diagram is arranged so that the tests can be compared on the basis of the percentages of increase for different loaded lengths of span, as not only did the experiments most readily admit of such an arrangement, but this basis seemed the most reasonable that could be devised. For Prof. Turneaure's experiments, the loaded length of the diagonal web members was taken as the distance from foot of the diagonal to the nearest end of the bridge.

DIAGRAM A.

Maximum dynamic effect of moving load for each set of experiments for each loaded length of span.



Loaded length of span in feet which produces maximum stress.

One observation plotted at loaded length 55 feet, records an increase of 80 per cent. in the stress in the center diagonal of bridge No. 16 of Prof. Turneaure's experiments, which occured when the bridge was loaded from end to end (127 feet) with cars which produced a total stress, including dynamic effect, of only 900 pounds per square inch. This increase is no criterion as to the increase from dynamic effect to which the member is liable when the bridge is so loaded as to produce the maximum stress therein. All the other observations lie in a field closely bounded by two straight lines intersecting at a

point indicated by percentage 50 and loaded length 117. The suden change at this point in the direction of the boundary line is probably due to the fact that for short loaded lengths the chief causes of dynamic effect are the centrifugal pressure from the partly unbalanced locomotive driving wheels and the rapidity and impact with which the loads are applied, while for long lengths the chief cause is accumulative vibration.

The diagram indicates that percentages varying as a straight line from 100 at loaded length zero to 50 at loaded length 125, and a percentage of 50 beyond that length will cover the amount which should be added to the live load for dynamic effect.

It seems hardly likely that the effect of accumulative vibration will be as great in the webs as in the chords, but the writer would not recommend any reduction on that account in designing bridges.

The observations only extend to 207 feet, but accumulative vibration occurs in spans of much greater length and in one respect is liable to be more severe than on shorter spans as cars are the chief factor in producing accumulative vibration and cars are a greater factor in producing the maximum stresses in long spans than in short ones. On the other hand the impulses, the recurrence of which occasions the accumulative vibration, are lighter in comparison with the weight of the bridge for long spans than for short ones.

Further even if the same percentage of increase from dynamic effect occured in a long span as in a short one, it would be a smaller percentage of the entire stress and therefore less dangerous. Further for very long spans a cantilever type is usually used and the cantilevers would not be apt to vibrate harmoniously with the suspended trusses. From a consideration of these arguments pro and con it seems best to continue a 50 per cent. addition for dynamic effect up to say a span of 500 feet and to then gradually lessen the percentage till it reduces to zero at 1,000 feet.

All of the foregoing conclusions refer to single track

bridges. The liability to conditions which will produce great dynamic effect on more than one track at a time is quite remote, especially on very long spans. Should such conditions occur the general provision for safety, the provision for possible increase in loading, and provision for dynamic effect from the load on one track, would doubtless be sufficient without any provision for dynamic effect from loads on other tracks, except for spans less than 125 feet, for which some, though not full addition, should be made for simultaneous impact from loads on more than one track.

For very long spans the liability to a full load on all tracks and full dynamic effect on even one track, is so remote that it is not necessary to make full provision for the dynamic effect of the load on even one track. When trusses are liable to stresses from loads on more than one track, the maximum dynamic effect from the load on any one track as compared with 1.0, the possible dynamic effect from loads on all tracks, is about as follows:

For a symetrical two truss double track bridge....	0.7
For the intermediate truss of a three track bridge..	0.58
For a symetrical two truss three track bridge, about.	0.47
For the middle truss of a four track bridge, about..	0.42
For a symetrical two truss four track bridge, about	0.35

A simple rule which will approximately meet all the requirements of the case is to deduct ten for each additional track, from the percentage of increase indicated for the dynamic effect of the live load on a single track bridge.

The conclusions to which this analysis of the dynamic effect of the live load has led can be formulated as follows:

Let L=the static stress, moment or sheer from Live Load.

" S=the length in feet of the loaded portion of the span.

" N=the number of loaded tracks causing the maximum stress, moment or sheer.

" U=the percentage of increase from dynamic effect.
" I =the addition for dynamic effect of the live load; or briefly, Impact.
" $I=UL$.

The provision for the dynamic effect of the live load should be made by adding percentages as follows:

For a loaded length of span less than 125 ft.,
$U=(100-0.4\,S)-10\,(N-1)$ ....(18)

For a loaded length of span from 125 ft. to 500 ft.,
$U=50-10\,(N-1)$ ....(19)

For a loaded length of span over 500 ft.,
$U=(100-0.1\,S)-10\,(N-1)$ ....(20)

The percentages for various loaded lengths are given in Table No. 11.

The greatest speed observed during the tests on which the foregoing rules are based was about 70 miles per hour. Greater speeds occasionally occur on some roads, and may become frequent on many roads, and such greater speeds carry with them the liability to greater impact on short spans. Inasmuch, however, as the provision for possible increase in live load, plus the provision for impact, herein recommended, makes a greater addition to the static stresses in the floor system and light web members, than is customary, and inasmuch as greater speed and greater load may not both occur, it was not deemed advisable to make a general recommendation for a further increase over current practice. In special cases, however, it may be advisable to increase the provision for impact on short spans.

The dynamic effect of the live load at train speeds less than 20 miles per hour was found to be very small in the Robinson, Turneaure and Baltimore & Ohio Experiments, which confirms the wisdom of the usual practice of running slowly over bridges known or believed to be unsafe. Orders for slow speed, apart from the inconvenience they cause, are not a sat-

isfactory remedy for weak or overloaded bridges, as there is some danger that the orders will not always be heeded, but they are a precaution which, with care, may prolong the life of an old bridge.

TABLE NO. 11

Percentages of increase from the Dynamic effect of the Live Load.

S Loaded Length of Span	Percentages of Increase				S Loaded Length of Span	Percentages of Increase			
	No. of Loaded Tracks					No. of Loaded Tracks			
	1	2	3	4		1	2	3	4
0	100	90	80	70	520	48	38	28	18
5	98	88	78	68	540	46	36	26	16
10	96	86	76	66	560	44	34	24	14
15	94	84	74	64	580	42	32	22	12
20	92	82	72	62	600	40	30	20	10
25	90	80	70	60	620	38	28	18	8
30	88	78	68	58	640	36	26	16	6
35	86	76	66	56	660	34	24	14	4
40	84	74	64	54	680	32	22	12	2
45	82	72	62	52	700	30	20	10	0
50	80	70	60	50	720	28	18	8	0
55	78	68	58	48	740	26	16	6	0
60	76	66	56	46	760	24	14	4	0
65	74	64	54	44	780	22	12	2	0
70	72	62	52	42	800	20	10	0	0
75	70	60	50	40	820	18	8	0	0
80	68	58	48	38	840	16	6	0	0
85	66	56	46	36	860	14	4	0	0
90	64	54	44	34	880	12	2	0	0
95	62	52	42	32	900	10	0	0	0
100	60	50	40	30	920	8	0	0	0
105	58	48	38	28	940	6	0	0	0
110	56	46	36	26	960	4	0	0	0
115	54	44	34	24	980	2	0	0	0
120	52	42	32	22	1000	0	0	0	0
125 to 500	50	40	30	20					

These advance copies of the last two papers are published prior to their presentation to the Society. Mr. Roberts' article—"FLOODS AND MEANS OF THEIR PREVENTION IN OUR WESTERN RIVERS"—*will be discussed at the September meeting; that by Mr. Prichard on* "THE PROPORTIONING OF STEEL RAILWAY BRIDGE MEMBERS," *at a date to be named later.*

DELMAS L. MACOMBER.

Born December 22, 1865.

Joined the Society March, 1903.

Died March 12th, 1907.

Delmas L. Macomber, manager of the Pittsburgh office of the Pratt & Whitney Co, of Hartford, Conn, died suddenly in Pittsburgh Tuesday evening, March 12th. While he had not been in good health for some time, his death was wholly unexpected and was a great shock to all who knew him.

Mr. Macomber formerly resided in Hartford, entering the employ of the Pratt & Whitney Co. in 1886, working at the bench and also looking after the erection of machinery. His value was soon recognized and in 1896 he was sent to Russia to install a very important small arms factory for the Government. Soon after his return home, the Pratt & Whitney Co, through their London agents, received an order for a complete plant of machinery to be used in the manufacture of bicycles for the Yorkshire County Cycle Co., at that time one of the largest and most up to date concerns of its kind; the contract calling for the services of an expert to erect and put in running order all of the machinery. Mr. Macomber, owing to his wide experience, was selected as the best man to send, and in the Fall of 1898 he went to England for that purpose. Mr. Hepworth, the principal owner of the Cycle Co, soon recognized Mr. Macomber's ability, with the result that he offered him the position as Works Manager, which he accepted, remaining there about two years. Early in 1901 he returned to his native land and entered the employ of the American Radiator Co, Buffalo Branch, where he remained until re-entering the service of his former employers, the Pratt & Whitney Co, as their Pittsburgh Sales Manager, which position he held at the time of his death.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

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Floods and Means of Their Prevention in Our Western Rivers.

BY T. P. ROBERTS,*
Past President.

DISCUSSION

BY HARRY J. LEWIS, MORRIS KNOWLES, WILLIS WHITED, E. K. MORSE, CHESTER B. ALBREE, EMIL GERBER, J. P. LEAF, SAMUEL A. TAYLOR, F. Z. SCHELLENBERG, CHAS. F. SCOTT, B. M. HOKANSON, GERALD FLANAGAN, EDWARD GODFREY.

An advance copy of this paper appeared in the July Proceedings.

At the request of the President, COL. ROBERTS opened the discussion by reading parts of his paper and commenting on the same. He was followed by

Harry J. Lewis: The flood of March 15th, 1907, is of especial interest to the City of Pittsburgh for several reasons:

First—It reached a stage in the main portion of the city which exceeded all previous records and was about two feet higher than that of February 4th, 1884, the one next approaching it of which there is an authentic record.

Second—The last flood was for the most part local to Pittsburgh and vicinity and came from a rainfall which was

* Civil Engineer, U. S. Engineers Office, Pittsburgh.

not unusual except in a comparatively small portion of the drainage area above the city. It does not appear that the snow lying on the drainage area and which came out with the rain and thaw was unusual in amount, or that it came off more rapidly than may be expected at any time.

Third—The drainage area of the Allegheny River had been at least partially cleared of the winter's accumulation of snow about the first of February, thus removing a large amount of water which otherwise might have been an element of the main flood six weeks later.

Fourth—The recorded stages of maximum high water above and below the city were not up to those of preceding floods.

It would seem, therefore, that the flood of March 15th, 1907, was local to Pittsburgh, and that it resulted from conditions which cannot be termed unusual and which may be exceeded at any future time. It is quite possible, in fact, that the total run-off was greater in 1884 and also in 1892.

This local intensity of flood at Pittsburgh without corresponding high stages at points above and below in proportion to previous floods, leaves the inference moderately plain that something has occurred to decrease the efficiency of flow section of the river channels in this vicinity since 1884. It is only necessary to compare the present channel of the Monongahela within the city limits of Pittsburgh with what it was in 1884 to see that a given quantity of water must either take a longer time to pass through or else rise to a higher stage. The encroachments of railroads and manufacturing plants have completely obliterated the broad, easy slopes of the originally valley and brought steep banks right up to low water mark. The storage capacity thus taken away is of course trifling when compared with the total of the whole valley, but the reduction of flow section at flood stage is a more serious matter and must amount to a considerable portion of the old valley. The lower Allegheny and the upper Ohio Rivers have been filled in after the same manner, thus concentrating the effects of this work in such a way as to increase the flood

stage in the City of Pittsburgh. For it is undoubtedly true that if a given amount of water is to flow through a reduced channel in the same time as through the original larger channel and without material change of grade, the smaller channel will produce a deeper flow section or, what is the same thing, a higher stage.

It may be argued that the old river channel was narrow at widely separated points and for short distances, but these would not retard the flow as would a channel reduced to the same section continuously for some miles.

With the above conditions, it would seem entirely rational to expect higher local floods in Pittsburgh with the progress of this filling of the river valleys, and this is verified by the facts.

It is also argued that the cutting of timber in the drainage basins of the Allegheny and Monongahela Rivers has allowed the rainfall to reach the channels more promptly and thus increase the flood stage from a given amount of rainfall. This argument has been challenged by the production of records from Europe which seem to bear out the opposite view, so that it may be of interest to discuss the actual conditions in question.

The early clearing in the watersheds above Pittsburgh was for the purpose of securing lands for farming and grazing, and the natural tendency would be to select the best and most level portions of the valleys and uplands, leaving the steeper hillsides and narrow valleys in timber. As these first cleared areas were brought under cultivation, and the soil kept loose by plowing, their capacity for the retention of rainfall would approach to some extent that of the wood mould in the original forests. This process of natural selection of the best ground for clearing probably continued up to forty years or so ago, the timber from new ground being sufficient for all the needs of the people. In later years the demand for timber has outgrown the supply from clearing for cultivation and thus has led to the cutting of timber on the steep slopes. This latter area is the one which sheds its

water with the greatest ease when uncovered and on which wood mould exerts the greatest retarding effect on run-off, and it is probable that nearly all of this area now cleared has been cut over within the past twenty-five years.

There is probably a balancing effect as between wooded and cleared areas on gentle slopes, in that the timber canopy tends to preserve snow for the general spring thaw which would be reduced considerably by partial thawing on open ground. This is not so true of steep slopes, as they are generally away from the full force of the sun and hold their snow till a general thaw, whether protected by a timber canopy or not.

If the above is true then the clearing of the steeper slopes in a drainage basin becomes the main factor in the increase of flood stage from taking off the timber, as when cleared they give up practically all their water in a general rain and thaw, a large portion of which would be retained in the wood mould if covered by timber.

The scour of the steeper slopes will increase as they are deprived of their covering of timber and wood mould and thus add to the amount of silt to be carried by the rivers in flood periods. This introduces a new source of filling material for the deeper pools where grades are easy and gives the river a tendency to raise its average bed with consequent reduction of flow section for a given stage.

A study of the flood records as far back as authentic information can be obtained suggests very strongly a gradually increasing stage of maximum high water at Pittsburgh, no matter what the actual causes may be. The reductions of channel together with the later cutting of timber from steep slopes are factors working to increase flood stage which would seem to be of prime importance, but whatever the cause, the losses from damage to property and from stoppage of industries remains the same.

It is quite possible that a good deal may be done in the way of flood control in our upper rivers by state and government agencies, but these things are likely to come slowly and

may never do more than neutralize the opposing tendencies which appear to make for higher floods at Pittsburgh, and it is therefore important to examine the remedies which the city may apply with means which are under its own control.

The greatest losses from floods occur in those portions of the city in which the streets and main floors of business houses are submerged, as all traffic is cut off, in addition to the natural damage from complete overflow. It is possible by modern methods of water-proofing to construct a basement so as to practically exclude water which does not rise above the street level, but it is a very different matter to protect a building from water which rises above the curb level and at the same time adapt it to the every-day needs of business and occupancy.

The most rational and effective remedy against flood damage within the control of the city would be to raise the street grades in areas subject to submergence to a safe height above maximum flood level. The first move along this line would probably be the establishment of revised street grades with the accompanying requirement that all new construction should conform thereto. When a sufficient portion of frontage on a square had been rebuilt to the new level, the sidewalks could be raised and steps used at street corners, and as soon as this had been done property owners would be ready and anxious for elevation of the street as rapidly as conditions would permit.

It would probably be best to take this work up by districts, selecting first a small isolated one, such as that around the intersection of Wood and Water Streets, and after the utility of the improvement had been demonstrated, there would likely be a demand for its extension to other parts of the city. Building improvements are retarded at the present time in the areas subject to submergence on account of the flood hazard, and with this removed the lower Penn Avenue district, for instance, would be opened to improvement by the best class of buildings.

To offset the expense incurred by the city in these improvements there would be an increase in taxable values from a better class of construction and occupancy which would be permanent even after the cost had been wiped out and the limited business section would receive a valuable addition at less comparative cost than that involved in cutting down the "hump".*

Morris Knowles (*as revised and extended by the author*).

BROAD CONSIDERATION.

The Society is indeed to be congratulated upon securing this paper upon so important a problem, which is worthy of much consideration and which, if rightly solved, will produce much benefit to this community. The writer deserves our thanks and, although we cannot so officially express them (he being a member) we all undoubtedly join in appreciation of the careful and thoughtful way in which he has brought together so much valuable information for our consideration.

It is interesting that, without any previous conversation with the speaker who has opened the discussion, I have been inclined to view this matter of "Floods and Their Prevention" from an entirely different standpoint. My appeal is essentially for the broad conception of this subject, rather than the purely local one.

It is far from the speaker's intent to in any way criticise the conclusions of one who has had such long and valuable experience with the river interests and who is, by training and learning, so well qualified to express positive opinions in regard to this and other waterway problems. He would prefer to have such remarks as he may make considered in the nature of interrogations, to bring out other points which have perhaps not been fully emphasized and to bespeak for our attention the claim that we should not at once disregard the availability of reservoirs to lessen floods without a thorough investigation; furthermore, to bring about, if possible, a broad contemplation

* The elevated ground, so-called, on which the Court House stands.

and discussion of the whole subject, rather than the narrower one of benefiting this city simply, and of it, the downtown portion.

This subject is one of the most serious which this Society and community can have before it for discussion at this time. This is so for many reasons, as it affects us in many ways, several of which are as follows:

First—The vast property interests, not only the downtown stores and office blocks, but the factories and mills.

Second—The laboring man, mechanics and other wage-earners, who lose employment during the period of floods.

Third—The farmers who are delayed in crops and whose cultivated areas may be injured, although sometimes the flood detritus may serve as valuable fertilizer.

Fourth—The rail transportation interests of our valleys, which are seriously hampered at times of flood.

Fifth—The river transportation interests, which are disturbed at such times; although at the beginning and end of floods navigation may be aided.

Sixth—The healthful condition of our streams, as related to the dilution of sewage and as concerned with the purity of water supply.

It is easy to be selfish and it is particularly true that this large, growing and wealthy city is likely to regard itself capable of solving any problem, however difficult, and doing this entirely for itself, without either help or co-operation from other interests. While it is true that we are now beginning to think of union with other municipalities in the annexation of territory, and thus secure a more economical management of civic affairs for this valley, even this is somewhat late. We have noticed that, in the solving of the water supply question, Pittsburgh was content to go it alone, so to speak. While, by a thoughtful consideration of what may come up, it will be possible at some moderate expense, better than by building separate works and independently, to provide for the water supply of the annexed territory in connection with the improvement and filtration, how much better it would have been.

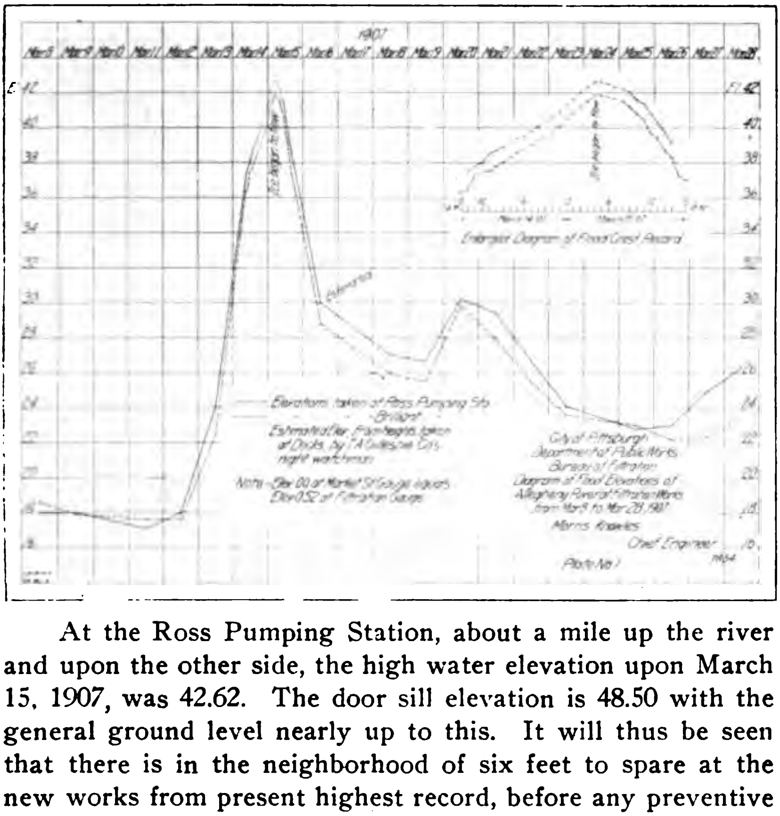
and really more economical in the end, if a broad project had been thought out in the beginning and a metropolitan water district formed, as has occurred in other places. The lack of co-operation was recently noticed in regard to the Nine Mile Run sewer problem, where it appears impossible for adjoining interests to secure an harmonious solution as a whole, with the evident result that each seems to be going alone, when a more economical disposition would have been obtained by united action. It is important to dwell upon this, for if, in the discussion of the sewage problem for this entire valley, this idea of separate action prevails; it will lead to much greater expense than with the combined and co-operative energy.

FLOOD OF MARCH, 1907.

The President has referred to the fact that we may have had some experience with the recent flood at the new filtration works. It is true that we improved this occasion to obtain considerable data, which I am pleased to give you at this time. The flood did not seriously affect either the construction or condition of the works. While the water was dangerously near putting out the fires at Brilliant Pumping Station, the new station is designed several feet higher and it is hoped that it will forever be beyond such danger.

The facts at Brilliant are as follows: The high water mark was at elevation 42.1 City Datum, although it was a little lower in the interior of some of the boiler rooms. The elevation of the floor and door sills is, in general, 41.3 feet, although some of the floors were slightly lower. In two houses, in which the grates were as low as the floor, or lower, bulkheads were built across the doorways, so that the water was kept out. In one of these houses the horizontal grates would have been entirely out of commission and in another, having inclined grates, the fires would have been three-quarters under water, if these dams and bulkheads had not been built. In a third boiler-house the inclined stokers were high enough to be beyond danger and, in another, the water was a few inches up upon the inclined grates. It will thus be seen that the danger at Bril-

liant Pumping Station is imminent and something should be done to prevent recurrence, because it is of little avail to have the new works beyond danger if Brilliant Pumping Station may be put out of commission, as all of the water must be lifted finally at this station.



At the Ross Pumping Station, about a mile up the river and upon the other side, the high water elevation upon March 15, 1907, was 42.62. The door sill elevation is 48.50 with the general ground level nearly up to this. It will thus be seen that there is in the neighborhood of six feet to spare at the new works from present highest record, before any preventive measures will need to be taken. But, in addition to this, there are six door openings, only, about the building and these are arranged with stop-plank channels on either side of each door, with stop-planks furnished and available, ready to be dropped into grooves at the first sign of danger. The elevation of the top of these channels is 54.50, or just about that of the window-sill openings about the building. It will thus be seen that pre-

cautions have been taken to keep this station from being disabled, even with an extraordinary flood.

Thinking it would be of interest to show the progress of the recent flood, we have plotted the river heights, at both the new and the old pumping stations, during the period from normal water and continuing during the flood until normal river stage was reached again, all of which is shown upon plate No. 1. These records were customarily taken once a day, but, during the progress of the flood, there were frequent observations taken at other places. even after the regular gauges were submerged, which enabled us to plot a continuous curve showing the record. The abrupt rise is particularly to be noted, as well as the long time of subsidence. This suddenness of the oncoming is that which gives a flood its freshet-like appearance and really causes the danger; in other words, there is but little time to do anything after warning is received.

DIKES—LOCAL.

It is apparent that the local view of the problem, to confine the two rivers within their banks has even limited the study still further, viz, to the downtown portion of the city. A rough and approximate estimate of the cost of this work, shown on the plan on page 320, including walls, grouting and pumping plant, is about a million dollars, and this does not include appurtenant costs of changing street grades, property damages and similar expenses. That this is not an excessive or high estimate may be apparent from the fact that several years ago a similar estimate was made at Williamsport, Pa., of about $800,000, also, recent newspaper comments have said that the City of Allegheny contemplates the expenditure of something like $5,000,000 for similar work, including the filling of the low lands.

Granted that this $ 1,000,000 estimate is somewhere within reason, this provides solely for protection of the so-called down-town or commercial or store interests. What about the South Side? What about Allegheny? Furthermore, what about the vast mill interests up and down the streams, and

railway transportation interests? All were seriously endangered by the recent and previous floods and if this protection work be carried on, it may in a short time necessitate an expenditure equal to that required for reservoirs. The author well says:

> "Other walls, within the limits of Greater Pittsburgh, would, of course, be needed in the general scheme of protection."

The speaker presents for serious and thoughtful consideration, what effect would the building of such an embankment along the lower portion of the Allegheny and Monongahela Rivers have upon flood heights of territory above? Would not this confining of the stream, by increasing the flood heights above, raise a question of property damages? The late Kansas City flood is an exemplification of this. Many will say that the water on the overflowed portion does not have much velocity and that, if the bed be excavated close to the embankment walls, greater cross section will be obtained for the stream proper. We do know, however, that the rivers carry vast amounts of silt and sand and that the holes excavated by dredges are continually filling up. Also, the information obtained from the Mississippi levee situation, as well as that from some foreign rivers, shows that dikes and levees cannot always be depended upon for securing protection and, sometimes, the bed of the stream is raised above the surrounding country.

The author himself tells us that

> "The mere suggestion of raising river banks and streets * * * * affords no adequate conception of what else should be done to secure immunity from flood damages."

His reference, also, to the danger of strong currents undermining buildings and other structures seems to preclude a sense of security in relying upon the velocity being so slow that the cross section of the flooded area will not be missed. It is an insidious advantage, mentioned by the author, that the embankment method will likely appeal because of the possibility of independent action and of its lesser first cost; in other

words, a little can be done at a time and that gradually. Reservoir construction will probably show more expenditure at any one time, but is not necessarily greater in the end, as compared with the piecemeal solution of the problem.

GOOD IN EACH.

The speaker fears that this discussion has narrowed down to the relative advantages of erecting dikes or walls and of building reservoirs on highlands to hold back the freshet flows. This, if so, will be unfortunate to a large degree, because there is really good in both projects and both can be used to advantage. There are undoubtedly many places where the filling in of the ground to some degree, not to an ultimate height of extreme floods, but to the general level of their surroundings, will deprive the floods of their serious danger and at the same time render property more valuable and available for other purposes than for which they are now used.

The unfortunate conclusion of the previous discussion, of about 55 years ago, was to defeat a thorough investigation; for each seemed to see the good in his own project, only, and errors in that promoted by the other. That which was needed then and is still urgent, is a complete study of the whole problem, considering all factors and taking sufficient time to secure an abundance of data and to make surveys; so that intelligent estimate of cost can be prepared upon each plan, in order to reach the best conclusions. The error of the previous agitation against reservoirs was based upon false premises, because careful investigations would have shown the possibilities of certain things which were rejected as unattainable without sufficient evidence.

It is to be regretted, in this connection, that his Excellency, the Governor, in his wisdom, decided to veto the recent authorization of the Legislature, to expend $20,000 for such investigations to ameliorate flood damage in this State. This very likely would have been ample to have made considerable progress and really obtain quite conclusive evidence in regard to the best thing to be done. Prior to the building of the

reservoirs on the upper Mississippi $10,000 was spent in 1868 for surveys, investigations and report, and $5,000 was expended upon similar investigations in the arid regions of the West. Money employed for investigations is wisely appropriated and ultimately leads to economy; as it frequently prevents unwise expenditures upon impracticable schemes. Even upon one that is determined as feasible, the data secured with the original outlay is available in carrying out the work.

EARLY DISCUSSIONS.

It is profitable for us to turn back and reflect upon some of the earlier discussions upon this same subject, those to which the author has referred—viz—of Messrs. Ellet, Roberts and Morris, from 1853 to 1857. Col. Ellet's monograph was the outcome of investigations to prevent floods and to improve navigation upon the Mississippi and Ohio Rivers and it is important to remember that many of the arguments for and criticisms against his scheme and in favor of the "locks and dams" method were due to the latter portion of the plan as much as to the former. That he had in mind, however, the elimination of the danger of freshets is evident from his reference to the flood at Wheeling of March, 1841, of which he states that about 44,000,000,000 cubic feet would be necessary to render such a flood harmless at Wheeling, and refers to the fact that such a reservoir, equal to four miles square and nearly 100 feet deep, would supply actual discharge for 50 days at a depth of five feet and

> "contain all the water that is necessary to hold back, to protect the upper portions of the valley from injurious effects of ordinary floods."

He states that

> "a dam, no higher than some of those constructed for the canals of this country, may be built upon the Allegheny * * * * capable of supplying the whole volume of water * * * * equally available sites can be found among the tributaries of the Monongahela."

Col. Ellet states, however, that although computations have been made to show reduction in extreme flood height,

> "there are many interests of society which would be promoted by a further extension of the system and an ultimate approach towards equalization of the daily discharge."

He pictures conditions of the Ohio and Mississippi Rivers if such a result were accomplished, which makes a very attractive outlook, and shows his broad conception of the whole problem. He also shows an appreciation of the fact that such work will require skilled and proper maintenance for its thorough realization. He evidently realizes, also, the bias against his position for he states,

> "The writer can scarcely hope immediately to remove the suspicion and distrust with which the first announcement of his plan was met by the public; but yet he believes that the period is past when prejudice or doubt can long resist the force of demonstration."

The paper by Col. Milnor Roberts, from the Journal of the Franklin Institute for 1857, is largely a discussion of why reservoir sites cannot be found upon the Allegheny and Monongahela River watersheds. There are, incidentally, also criticisms offered, that if they were found, such basins would be injurious to the health of people in the vicinity, that they would cost too much and that they would be full and thus not usable for the purpose of preventing freshets when most needed. Both of these papers, as well as the one reviewed by Mr. Elwood Morris, are worthy of careful perusal by students of this subject.

There are many abstracts in the latter which are well worthy of our consideration at the present time, because they refer to the necessity of surveys to demonstrate the various truths.

In one place he states that he is

> "fully satisfied that an adequate survey, alone, is all that is necessary to find adequate sites for reservoirs, and to demonstrate both the practicability of the plan and its pre-eminence over all others."

Again:

> "All of these questions are legitimately to be decided by surveys alone, conducted especially for the object in view."

He calls attention, furthermore, that the criticisms have been derived mainly from studies for railways and indicates that such is not adequate to decide the availability for reservoir purposes. Once more he states

> "The only difficulty in the reservoir plan appears to be the discovery of suitable sites for the artificial lakes, and this single objection—it can hardly be doubted—a skillfully conducted survey will effectually remove."

With such statements as these before the Congress at that time, it is to be regretted that money was not appropriated for the purpose of securing the necessary data to thoroughly solve the problem.

The present author, in a paper before the Engineers' Society of Western Pennsylvania, Volume IX., in re. "Increasing Navigable Depths of Upper Ohio River," also refers to the previous paper of Col. Ellet and states,

> "The conception was certainly a grand one * * * * opposition * * * * thus inaugurated, lead to neglect and its final abandonment. It was simply one of the things 'too good to be true.'"

The author also notes that there were encouraging reports from the workings of reservoirs in Upper Mississippi, but calls attention to the fact that there are no such sites upon the upper Ohio for similar purposes; although later he refers to the possibilities upon the Youghiogheny, Kiskiminetas and other tributaries, of storing two and one-half billion cubic feet and states that he does not think there would be any trouble to operate such a system, based upon a knowledge of the workings of the United States Weather Bureau Stations. The regret is, that with all this discussion, no material progress was made to have a comprehensive study inaugurated.

OBJECTIONS TO RESERVOIRS AND ANSWERS.

Both the past and present important arguments against reservoir systems have been two. First, sites are not available; second, reservoirs will be full when most needed to prevent floods. The other reasonings, viz, effect upon the health of the community and danger from ice are hardly weighty. For the first, it is evident that some of the most healthful places in the world are near lakes and ponds, both natural and artificial, and, in regard to the second, the usual type of spillway through rock on the side of reservoir would prevent any danger from ice. The final objection is that of excessive cost and this will always remain to be a most important criterion after all other factors are determined. But, if it is true, according to recent newspaper reports, that the flood damage in Pittsburgh district alone was $10,000,000, and that there may be two or three such floods in a century with numerous smaller ones of lesser expense, but still important; it can be readily seen that a large expenditure of money is justifiable. It then remains to be determined, simply, whether the combined cost of numerous walls, dikes and attendant expenditures is greater or less than for a complete reservoir system, or whether partial expenditure of both is wisest.

Answering the first of the arguments mentioned in the previous paragraph; surveys, as previously stated, would have prevented the error. A study of the recent topographical maps (although we do not yet have a complete issue covering the entire watersheds of the Allegheny and Monongahela Rivers) shows that there are a number of sites upon both rivers at which it may be possible to build dams and impounding reservoirs; some of which would be among the largest which have yet been built in the world, and some as well, with dams that are low considering recent modern engineering practice. A cursory study of the map shows five or six such sites available, with varying capacities from 20 to 350 billion gallons. It is undoubtedly true that not all of these and perhaps only a few are now possible or practicable, on account of the vast

interests involved and damages that would be occasioned, but many of them would have been practicable in the early days, before important railways and town sites were built in the valleys. To illustrate, one such reservoir of enormous capacity seems possible on the Connewago Creek, with a drainage area of about 700 square miles, where a dam of only about 50 feet high and something over a mile long would have made about the largest artificial reservoir in the world, or something over 350 billion gallons. While this is not to be thought of at the present time and perhaps even then good reasons would have been found for not building, it is not probable that all of the sites to be found upon the watersheds would have been found unavailable. Accurate surveys, alone, would have determined this.

Regarding the second objection, that such reservoirs would be full when most needed for prevention of freshets: This should receive a second thought, for at first glance it does not seem as if human foresight could plan that reservoirs should not be full at times when floods are likely to occur. Yet we know that in the practical operation of the reservoirs of gravity water supplies, they are so managed that they are drawn down most of the time, some distance below the top. With the larger systems, in what we call a complete development of a watershed, there will still be a large amount of water in storage for ordinary purposes and at the same time have considerable capacity near the top for filling in case of a heavy rain. There are some reservoir systems arranged for a very complete development of the watershed, which never fill up in six or eight years; in the length of a very dry spell the reservoir will continually be below flow line and during a period of wet years the reservoir will be filling up. It is to be expected, in a system of reservoirs generally distributed over watersheds and operated for the particular purpose of leaving room for heavy rains and thus storing the freshet flows, that they would be kept down at those seasons of the year in which the greatest danger will likely occur. It is also to be commented upon that, with a reasonable spillway upon the side of reservoir, less than the total width of the stream, it is possible to

have a heavy downpour occur with a full basin and still pile up the water above flow line; on account of running away over the spillway more slowly than the gathering ground brings it into the basin.

The author of the paper has indeed presented a seemingly strong argument, when he inquires what good would a reservoir system have done in the recent flood. He calls our attention to the fact that the rainfall was over a limited area, compared with the whole watershed, stated to be one-half, and this caused the most excessive flood on record at Pittsburgh. Reference to the flood diagram in Plate 1 shows that it was a sudden rise, but further review of the watershed conditions shows that for a few days there had been general rain upon the watershed and that, together with the snows contained upon the areas, would have contributed to a considerable flow over entire area.

A valuable table for record is given upon Page 317, but in order to show the totals, as well as the general distribution over the watersheds, the speaker presents in Plate No. 2 a map of the two watersheds, showing the location of the rain gauge stations and the total rainfall for 120 hours, from March 10th to 15th. It is quite within the realms of possibility that, with reservoirs distributed over the two drainage areas, some of this fall would have been retained. It is worth while remembering, however, that there is no universal panacea for all troubles, nor any constancy of conditions and it may at any time happen that a new set of conditions may cause a flood of entirely different character and magnitude than any which has yet happened. But it is true that a lower stream flow from the uplands with a large rainfall in lower regions would have produced a less excessive flood at Pittsburgh.

INVESTIGATIONS ELSEWHERE.

Among the most important contributions to the subject of reservoirs and their influence upon stream flow, are certain parts of the reports of the Chief of Engineers of the United

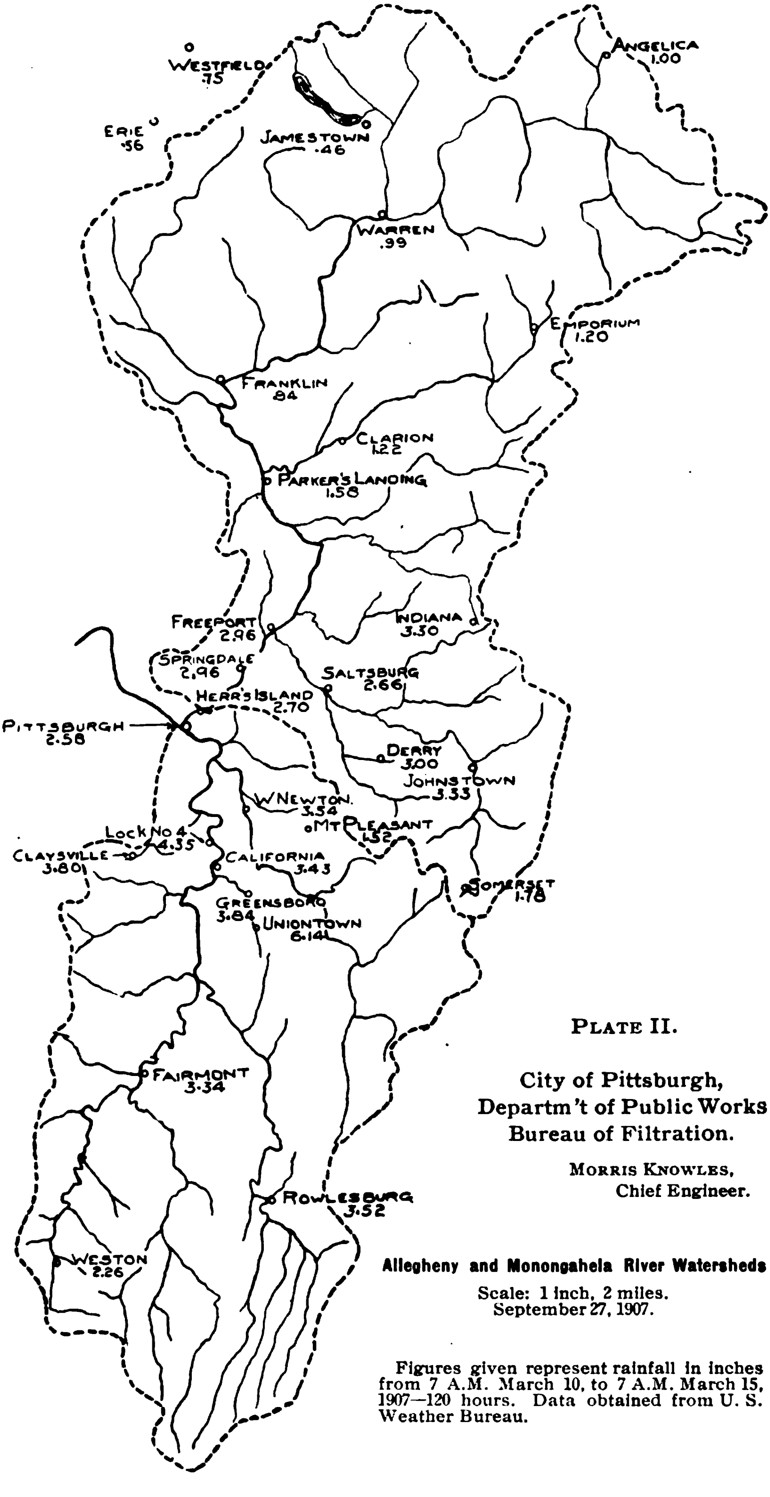


PLATE II.

City of Pittsburgh,
Departm't of Public Works
Bureau of Filtration.

MORRIS KNOWLES,
Chief Engineer.

Allegheny and Monongahela River Watersheds

Scale: 1 inch, 2 miles.
September 27, 1907.

Figures given represent rainfall in inches from 7 A.M. March 10, to 7 A.M. March 15, 1907—120 hours. Data obtained from U. S. Weather Bureau.

States Army, from 1892 to 1897, in regard to the upper Mississippi River storage reservoir system and again in the report for 1898 of Col. H. M. Chittenden in re. reservoirs for the arid regions of the west.

In the former it is noted that there were 41 projected reservoirs, to cost about $1,800,000, and this sum is low because of the fact that many of the natural lakes required raising a little simply to make a large capacity. The agitation for these reservoirs began in 1868 and it was 1874 before the government ordered a survey; seven sites for reservoirs being found to hold 95,000,000,000 cubic feet, with heights of dams from 4 to 24 feet and lengths from 4,000 to 400 feet, at an estimated cost of about a half million dollars. Most of these reservoirs were built when there were no roads over which to transport materials and no railroads and no settlements near. Many of the dams, being built of wooden logs, now require repairing or rebuilding to be placed in permanent condition. The last is important, for there are many types of dams, other than of masonry construction, which are possible for holding back water, and some more permanent than the log and rock-filled dam.

Col. Chittenden in his excellent report has given a resume of the existing dams of the world and a statement of similar projects for storage of flood flows and the reasons for the nonfulfillment of some. The whole article is a most valuable one and worthy of thorough perusal. He mentions that the Rhone flood in France in 1856 caused a damage of $6,000,000, and submerged 540,000 acres of land, and calls attention to the fact, however, that

> "the protection of river towns by works intended to confine floods to proper limits, was reported practicable, at a total cost of about $4,000,000."

The question of reservoir construction was considered, studied and examined in the most thorough way, and decided adversely in regard to two rivers and favorably in regard to

the third. The particular cost upon the Rhone drainage area was estimated to be about $13,400,000.

The estimated cost of these reservoirs in the arid regions of the United States was $2,700,000, and a comparison of these reservoirs with other noted ones in the world, some of which are taken from his report and some from other sources, is presented, in order to show something about the magnitude and extent of similar projects elsewhere and not with any idea of affording a comparative basis of cost for our local conditions. This data is given in Table 1*. The following quotations taken from Col. Chittenden's report are valuable and the speaker thinks are worth repeating, and becoming a part of the Society records of this discussion:

> "The most formidable evils arising from this variable condition of natural streams are experienced in the deficiency period, but the period of excess has likewise great disadvantages. It not only comes at a time when ordinarily there is least need of it, but it not infrequently brings with it appaling disasters. Among the most calamitous of natural visitations, considering their frequency and general distribution, are great floods. They hold the record even above earthquakes and storms. They mark the history of nearly every stream, great or small, and the loss of life or property from this cause, in the history of the past, transcends calculation."
>
> "It is not surprising, therefore, that one of the chief concerns of the engineer is the amelioration or prevention of the evils of this unfortunate arrangement of nature. Millions of dollars are annually expended to make up for the deficiency of water in seasons of drought, and like sums to prevent or alleviate the evils of excessive flow. Singularly enough, the measures generally adopted are put forward in disregard of one of the commonest rules of scientific practice. If an evil condition of things is to be corrected, the rational method of procedure is to remove the cause. In all river engineering, however, the measures adopted look only to the palliation of results, and leave the cause untouched. River channels are dredged out in low water, and levees are built to protect from floods in high water. Scarcely anywhere is the effort made to prevent the recurrence of either high or low water. It would naturally follow that, if great evils result from the variable flow of streams, the pri-

* See "Engineering Data" in the present number for this table.

mary and fundamental object of the engineer who is called upon to correct them would be to make this flow uniform. Whether or not this object is possible of realization (and if it is by what means) is therefore one of the first questions which should be settled in any comprehensive project for the regulation of the flow of streams."

"Inasmuch as human agency can exercise no appreciable influence over those climatic conditions upon which variations of stream flow depend, such as the precipitation of moisture and the melting of snow, it is evident that the ultimate causes of the evil conditions just described must ever elude the efforts of màn to control them. The sources of the streams are clearly destined to remain as variable in the future as in the past. The only possible method by which uniformity of flow can be secured must, therefore, be by storing the surplus waters in seasons of flood and releasing them in seasons of drought. The agencies employed for this purpose are called reservoirs (Latin reservare, to keep back)."

* * * * * * * * * * * *

"At first thought it would seem that in storage reservoirs lies the whole solution of the river problem. To store the surplus in flood season and use it in the season of drought ought apparently to strike at the root of the whole difficulty, and to render unnecessary those palliative measures which alone have hitherto received the sanction of the hydraulic engineer."

* * * * * * * * * * * *

"While it is impracticable * * * * to imitate nature on the scale of her own work in the construction of reservoirs, her example has nevertheless been followed very extensively on a smaller scale. In fact, works of this character have been built for a variety of purposes since the remotest antiquity. The storage of water for feeding canals is a prominent example. The greatest reservoir systems yet constructed have been designed to maintain the navigable condition of natural waterways. Many reservoirs have had as a prominent reason for their construction the prevention of floods in the valleys below them, although this has seldom, if ever, been exclusive reason. Storage of water for city supply, the development of power, and other industrial uses is one of the most familiar of modern enterprises. Finally, the field of irrigation, which already presents many examples of great reservoirs, bids fair to outstrip all other fields in the production of works of this character. In all these examples of the reservoir construction the purpose has been to correct the inequalities of nature—to prevent the

rapid and destructive flow of rivers at seasons when not needed and to augment and reinforce that flow when the need does exist."

* * * * * * * * * * * *

"Every reservoir built along the course of a stream is, to some degree, a protection against floods in the valley below. The extent of this protection depends, of course, almost entirely on the ratio of its capacity to the flood discharge. * * * * When it is remembered that the volume of a destructive flood is only a part—probably always less than half—of the total flow of a year, it will be admitted that storage capacity equal to one-fourth of the run-off, well distributed throughout a watershed, will practically eliminate the evil effects of floods in its streams."

"It is not necessary, though important, that a reservoir should be empty when a flood comes. Even if full it still moderates the flow of the stream below, the effect varying directly with the superficial area of the reservoir when full, and inversely with the capacity of the spillway. In this respect it acts precisely as does a natural lake. For example, if the spillway of a reservoir or the outlet of a natural lake be of such dimensions as to require a considerable increase in the depth of water to give much of an increase of discharge, every increment of this depth of outlet means also an increment of the same depth over the entire reservoir. A flood passing such a reservoir will be reduced from a storage resulting from this increment, and before it can produce a full discharge it must fill the reservoir to the necessary height above the bottom of the spillway. A large reservoir is, therefore, even when full, always a perfect protection against sudden floods. In the case of long-continued floods it greatly retards the arrival of maximum effect and gives ample notice of its approach."

A discussion of this same subject before the Engineers' Club of Philadelphia, contained in Volume IX. of the Proceedings of that Society, 1902, furnishes interesting reading. The topic was the general flood discharge of streams and referred to the effect of floods of the last of February of that year and the one of December 15th, 1901, upon the rivers in the eastern part of the State. Mr. L. Y. Schermerhorn in commenting upon floods at Williamsport, Pa., west branch of the Susquehanna River, in 1889 and 1894, refers to a report made by Col.

C. W. Raymond and himself, in regard to the protection of that city. He states that the watershed was about 4500 square miles and, during the flood, the normal width of the river, of about 1000 feet, was increased to nearly 7000 feet. He continues as follows:

> "The plan which was recommended for protection against floods provided for the restoration, as far as possible, of the normal cross section of the river, and the construction of embankments along the city front, to confine the flood discharge of the river, provision being made to take care of rainfall and sewage upon the impounded city areas by pumping during such time as the river was in flood. The entire cost of the project was about $800,000."
>
> "The destruction of the forests upon the mountain slopes of our watersheds is the principal cause of the increase in flood volumes. * * * An eminent authority affirms that four-fifths of the precipitation in forests is detained by the surface of the ground, to be gradually given up to springs and lines of drainage, and only one-fifth delivered to the rivers rapidly enough to create floods. Upon the same slopes, denuded of forests, the proportions may easily be reversed."
>
> "While the construction of barriers, in front of large communities, for the exclusion of floods from rivers, is practicable, it can, nevertheless, only be applied in isolated cases, on account of its great cost. For a broad solution of the problem recourse must be had to the restoration of forests upon the watersheds of rivers liable to dangerous floods, with an effort to hold back the rapid discharge of water from the drainage areas; thereby reducing the maximum discharge and consequent height of floods, by giving the main recipients of the watershed a longer time in which to discharge the rainfall. The latter part of such a plan begins at the fountain-head of all lines of drainage discharge, and thence continues to the main affluent."
>
> "This system of holding back the rapid discharge of rainfall from watersheds, in connection with the restoration of forests on the mountain slopes, involves the checking of the rapid runoff in brooks and small streams by means of small porous dams. * * * * Such systems are already in operation in France, Germany, Italy and experience has demonstrated their practicability."

Under this heading we must not forget the recent studies of the Passaic Flood Commission; following the notable floods

on that river in March, 1902, and October, 1903. The damage from the former was estimated at $3,000,000 and from the latter $7,000,000. These conditions induced the Legislature of New Jersey to appropriate $20,000 for study and report. The commission reported in December, 1906, and recommended the building of a storage reservoir on the Pompton River, at an estimated total cost, including all damages, of $3,850,000, or of $7,400,000 when allowing for additional water supply uses. The reservoir planned is a large one, of 110,000,000,000 gallons capacity, with an earthen dam 3500 feet long and 95 feet high from rock base. The commission made this important statement:

> "The problems of flood regulations and water conservation in the Passaic drainage area cannot wisely be considered separately. The one must be a forerunner of the other."

OTHER REASONS FOR RESERVOIRS.

There are many other advantages which present themselves in considering the reservoir system, which should certainly make us thoughtful and make the project worthy of careful attention. Col. Chittenden has called attention to this in some of the remarks above quoted, and in another place makes the following statement:

> "The function of reservoirs will always be approximately the promotion of industrial ends; secondly, a possible amelioration of flood conditions in rivers."

The speaker cannot wholly agree with this statement, but at the same time wishes to call attention to several other factors and reasons for building reservoirs. Any means of holding back flood flows and lessening the damage will to some extent be of consequent advantages to other interests. First and paramount we think of the navigation interests; even with our well-planned slackwater scheme, there are times when it will be a benefit to have more water at dry seasons and any system of reservoirs could be so designed to help out at such times and provide greater quantity for lockage.

With the ever-increasing amount of sewage flowing into the streams, it is fast becoming a question of grave importance to have enough water to sufficiently dilute this, so that it will not become a nuisance to the community; this is, of course, particularly true with the pools of the slackwater system. Even if the matter of sewage disposal is taken up and pushed to a solution, there will still remain the street and roof washings, farm drainage and many other wastes, which for a long time will remain untreated and not be included in any such system, and the stagnant conditions of pools, while not perhaps to cause disease, may become disagreeable to the people.

There is another factor which is not the least important, although up to the present time it has probably not been given much thought. I refer to the water supply question of this valley. At the present time, Allegheny County is probably using something over 160,000,000 gallons of water daily for domestic purposes and in 25 years this may readily be expected to increase to 250,000,000 gallons; and this does not include about as much more, separately pumped for manufacturing needs. Recent gagings of the Allegheny River near Brilliant Pumping Station show an ordinary low water flow of about one and a half billion gallons in 24 hours. It is probable that during the lowest water period, of the driest year of a long series of dry years, this may become as low as six or eight hundred million gallons, with the probability that the Monongahela at the same time will not add much more than another hundred million on account of its topographical soil and drainage area conditions. It will thus be seen that in the future, when the water that has been used in the cities may be sent down in a trunk system of sewers, far below available pumping stations, the amount of water supply for this growing county, and entire valley even, will become a matter of serious importance and it is entirely within the realms of possibility that it will become necessary to build storage reservoirs for this purpose, if for no other.

FOREST INFLUENCE.

The forestry question has been touched upon this evening and someone has aptly said, the advocates for reforestration have all of the arguments but none of the facts, and I think it will be worth our while if we pause to consider why this may be so. The strongest argument against the benefit of forestry seems to be that you cannot prove the advantage by records of flow. I have endeavored to determine whether anything could be found out along this line from records about one of the New England streams, where the forests have been denuded for some time. The answer that comes to me is that it seems to be impossible to show any effect of the cutting off of the forests either in regard to flood, ordinary or minimum flows. Now all of our good sense and reasoning shows that the porous humus deposits of the forests, being an expanded condition of permeable soil, have a large amount of invisible storage and is generally ready to receive more, like a sponge. That these same forests, even when of deciduous trees, do prevent the melting of the snows in springtime longer than upon open areas is also true.

Why is it, then, one cannot prove the effect upon flows? The speaker believes that the reason is that there are so many other conditions which affect flow, such as the climate, the topography, the distribution of rainfall by seasons, in quantity and in location upon the watershed and changed character of the channels of the streams, both natural and artificial, so that it can never be said that all of the other conditions are alike, except the one, viz, the difference in regard to the amount of forests upon the watershed. There is no such thing as an accurate comparison between floods of today and floods of 50 years ago; one cannot determine all the facts to make comparisons. This, it appears, is the real reason why forest advocates do not have the records upon their side.

But then again, as in other matters, there are additional arguments for the saving of the forests and it is gratifying that many of these are fast coming to be realized by some of

the largest interests. The most important and one with the greatest effect, in the long run, is that the intelligent cutting of the larger trees rather than the wholesale demolishment, gives the greatest profit for all time. I was particularly impressed during this last summer by noticing how practical men of large affairs view this question. It was my good fortune while in a lumbering region of Maine, to come into contact with a representative of large concerns, obtaining material for some of the largest pulp mills of the paper trust. He informed me that it was not a fact that they like to cut out a forest completely, but it was rather the small companies and the farmers who were interested to secure all the value at once and who could not afford to wait and look ahead, who completely devastated a given area. He stated that the company's policy was to cut no trees smaller than 14" at the butt, unless in felling large trees, smaller ones were broken down, in which case they would be cleaned up. This permitted them in 20 years or so to go over the territory and again cut trees 14" and larger. This was evidently true; in going about through the woods I noticed a number of tracts in which there were good-sized trees, and I was told that some of these tracts would be cut over next winter.

The general clearing up of the farmer is due also to other causes than the desire to obtain most money in shortest time. Frequently it is due to ignorance or desire to obtain quick crops on a truck farm, thus cutting off and cleaning up a new territory instead of rotating crops upon the old. Thus allowing the other to be used as pasture land, or worse still, to go entirely without care. This means, without intelligent planting or attention, the ground is permitted to be worn into large furrows and gullies, allowing the soil and detritus to be washed into the streams; all of which goes to produce a quick run-off from watershed and also reduces the cross section of the streams, by filling up, and thus making the floods higher and water muddy and more unfit for use.

CONCLUSIONS.

In conclusion, therefore, the speaker wishes to emphasize the following: That we should have a broader conception of the whole problem and not a selfish consideration for one place; that there is good in both methods suggested; that there are many additional reasons for constructing reservoirs other than desire simply to diminish flood heights; that a careful survey and study is the only way to properly and finally solve the problem; that this opportunity should be used to so agitate and prepare the public mind that funds for this purpose can be obtained. It is a worthy object in which this Society and other civic organizations can unite in a strong effort.

Willis Whited: I am very glad to hear papers on engineering subjects that affect the general public, read and thoroughly discussed in this society, especially problems that involve immense sums of money and must require many years for their solution.

One reason is that a public officer, facing such a problem, can do little unless he knows that he is backed up by a strong, thoroughly-established, intelligent public opinion, and his success depends very largely on his ability to gauge public opinion and the extent to which he and those acting with him can mould and crystallize it. And they need all the help they can get from the engineering profession, and intelligent public discussion.

I might illustrate by the papers that were read at the last meeting of this society, those on the subject of sewage disposal. The State Board of Health is doing magnificent work in that line, but in doing their work they are constantly treading on somebody's toes, and there is always a possibility that unless they are effectively sustained by public opinion, the aggrieved parties will bring sufficient pressure to bear upon the Legislature to thwart the scheme, and have the powers of the board curtailed to such an extent that they are incapable of further usefulness.

As to the causes of the floods in Pittsburgh, there are several things that contribute. I will instance this: At the South Tenth street bridge the channel at pool full is about 700 feet wide. When the old bridge was built about 50 years ago the width was about 1300 feet. The river has been correspondingly narrowed at many other places. That water must go somewhere. It has scoured out the bottom to some extent, but not enough to make up for the narrowing of the channel. Higher floods follow, as a matter of course.

And speaking of the river spreading out as it rises above flood level, one speaker rather advised against raising the streets above flood level, or he suggested that if it were it would reduce the channel still more. I must respectfully take issue with him to some extent on that point, because the part of the area that is covered by the flood is so obstructed by buildings that comparatively little water passes over it, and the rise of the river due to the dikes or levees confining the water would not be so great as some people imagine.

One speaker suggested that the raising of the grades of the streets in the flooded district should be done gradually. Now, I respectfully beg leave to differ from him on that. The revised grades of the streets should be settled as soon as possible, and then all new buildings should be made to conform to the new grades. If we fix up a part of the city this year, as is done to some extent on Seventh Street now, and another part another year, and another part ten years more, in the meantime many large and valuable buildings will be built on the low grade which otherwise would be built at the higher grade, and as the new buildings will be much more durable, it will postpone for a good many years the consummation of the work that is desired and add immensely to its cost.

As far as the mills are concerned, the cost of raising to grade around them is, I think, largely a question of raising the bridges over the river and raising the railroad tracks leading into the mills. There is very little difficulty in this town in getting filling for nothing to raise grades of railroad tracks to almost any desirable extent. The grade around the mills

could be raised at a much less expense than some people imagine. It could be done gradually, but effectively. Though it would cost an immense amount of money, it could be done in such a way as not to interrupt business seriously, and I think they would be willing to pay their part of the cost.

E. K. Morse: The papers this evening have been somewhat of a surprise to me. Not that they are not correct in the statement that they make, but they are all of them contrary to what I had believed were facts. In the first place, Col. Roberts states that the forests, apparently, so far as he can see, do not affect our flood heights or our high and low water. That is so contrary to the opinion I had formed in my mind, from my own observation, that I will not attempt to argue it with him.

But I will say this, that while the government of the United States through its Forestry Department has not attempted to preserve the forests in the West, it has systematically where possible taken possession of, and will in the future as well as in the present preserve the headwaters of all our important streams, for two purposes, first and primarily, in order to preserve the constant and uniform flow of water from those sources, and secondly, to preserve its purity.

Now, whether the denuding of our forests in this commonwealth and others does or does not affect the height of our floods, or control the question of low water in time of drouth, I am not attempting to say; I have not the facts.

A few years ago I was surveying up the Mosquito Valley, which runs from Niles up to Jackson, Ashtabula, and for weeks I had been wading with the corps in water from ankle deep to hip deep. I came to several fields that were apparently dry and which they were plowing. Wading right out of the water I went over to the farmer and said, "How do you drain this?" It was almost level, and would take a level to find out which way the ground sloped. He said, "We clear it." Well, I was provoked. I thought he took me for a greenhorn, whereas I had been a farmer for over

twenty years. The next time we came to a plowed field, I went over to another farmer and said, "How do you drain these fields?" "Oh," he says, "we just clear it." I went back to the corps and said, "Level these fields; I would like to know how much higher they are than the water we are wading in. They did so, and found them practically the same level as the swampy grounds. That holds good not only there but also on my father's farms and on all the farms around the neighborhood where I was born. Those swamps in which I used to hunt pheasants and rabbits, in the winter time only, when they were frozen over, are now mostly cleared; some are drained and some are not, but there is where they raise the best crops today. I can only form one conclusion, and the same is borne out in my tramps in the headwaters of the Allegheny and Monongahela Rivers; I can only attribute it to the fact that the sun will evaporate the moisture out of the soil the minute the forests are removed. Over in Beaver County there is a road near Hookstown that I have traveled many a time, and I have never traveled on that road that I did not feel that I was either going to break the carriage or get stuck in the mud, summer, winter or any other season. And those of you who are traveling in automobiles know that when you come through the dust and go into the dense woods, you are getting right into mud puddles.

The only conclusion I can draw is that the forests prevent evaporation and that leaf mould acts like a sponge in holding the moisture. This being the case, I cannot see any other argument than that it will control, not so much floods, as our uniform flow when we need it for navigation and the interests of our cities along the rivers.

Now as regards the question of our floods, it may be possible to control them with a dam or dams, but I cannot sweep out of mind the fact of what an immense amount of storage it would have taken to control the flow of the water during the March flood, which was a little over 41 feet at Rochester and about 60 feet at Cincinnati, over 300 miles long, and run-

ning like a mill-race. How we are going to hold that volume of water in control and let it out at the right time, is too much of a problem for me.

There is just one other point and that is the one of narrowing our channels. They have been narrowed, right down to the very margin of what the law will permit. Even the slope of the harbor line has been taken advantage of in some places. But there is one other item that has not been touched upon in that respect. Up until 1897 there were only two bridges that I know of in this vicinity that were built on piles driven and cut off under water. Beginning at Forty-third Street, coming down the Allegheny and going up as far as McKeesport, on the Monongahela River, most of them were built on what is known as the grillage foundation. A dredgeboat would level off the bottom of the river, the masonry would be built on top of the grillage timbers (in a box) and sunk until it rested on the bottom. Today piles are driven, cut off under water and the timber grillage sunk on them in the usual manner for open caisson foundations. The result has been that nearly all the old bridges have to depend on riprap, and there is not one of the old bridges that would survive an ordinary flood if it were not for this riprap protection. In some cases the bottom of the grillage is above the bed of the river. Why? Because the channel has been encroached upon and the depth of the river has scoured, in many places ten or twelve feet below the original bed of the river.

Emil Swensson: I am glad to be present at this meeting, as I otherwise would have been deprived of hearing the explanation which Colonel Roberts made of his paper. This explanation gave me an entirely different general impression of the Colonel's ideas of this weighty matter, than I had received from simply reading his paper.

I twice read the paper through and the idea formed, as to the Colonel's arguments, was that he believed it entirely out of the question to control or regulate the floods of our rivers by means of storage reservoirs and reforestration. From

Mr. Knowles' remarks he seemed to have gained the same impression. Colonel Roberts seemed to argue that it was no use to partially regulate or control the flood-waters of our rivers, because it could not be so done entirely. Now, I understand that, although he does not believe that the forests have anything to do with the stage of floods in our rivers, he does not condemn the storage reservoirs entirely, but only arguing against their efficiency, because they would have to be so large, and, consequently, expensive.

Colonel Roberts, as well as most of the speakers tonight, seems to dwell more upon the details of the matter and the difficulties surrounding the accomplishment of the remedies for our flood-waters, than on the general proposition; in other words, they are very prone to judge the subject in general from the details and difficulties surrounding same. But that is natural, as we are always inclined to consider exceptions rather than general rules.

After listening to the discussion here tonight, I have gained the impression that we have mixed the subject considerably. The speakers seem to consider the removal of the cause of our floods in the same class with the protection against such floods. Neither the alleviation of the symptoms of a disease, nor the protection against the results of a disease, cure the disease itself, the cure for the disease being the removal of the cause.

The subject of Colonel Roberts' paper seems naturally to divide itself into two questions: First, the control or regulation of the flood-waters of our rivers; and, second, the protection of our cities, towns, villages and manufacturing plants against such floods, when they occur.

The first subject naturally comes under our National Government, as our rivers are navigable streams, over which the government has sole control, because the regulation of such flood-waters would be a benefit to navigation on these streams, be a benefit to the water supply, necessary for our population and our factories, and further, because it has an important bearing on the sanitation of the districts through

which such rivers flow. In the latter respects the state, as well as the national government, becomes interested in the matter.

The second division is entirely a local matter, each municipality being required to protect itself against damages by excesses of the elements.

The regulation and control of flood-waters in our rivers, although a very large subject, is by no means impossible. "Control and regulation" does not mean complete abolishment of floods. It means just what it says, to do whatever lies within our ability and means to take care of this amount of water precipitated at excessive rainfalls, to retard the run-off, thus reducing the stage of our floods and the therefrom resulting damages.

Storage reservoirs, located at the headwaters of our rivers, may not be of sufficient capacity to store all the rainfall, but whatever amount is stored will affect the flood stage at the time, and surely half a loaf is better than none at all.

We cannot expect to build all the necessary reservoirs at one time, and it probably will be too expensive to build sufficient number of reservoirs to fully take care of the excessive rainfall, but we can add more and more reservoirs from time to time, within our means.

Reforestration is a slow process and we can not expect to cover all suitable land with forests at one time and certainly not as much land as was once covered with forests, but we can gradually do so and certainly to some extent retard the run-off by same, within our means and to suit conditions. Thus the reforestration will to more or less extent retard the run-off from excessive rainfalls, reduce the stage of our floods and minimize the thereupon contingent damages along our rivers.

The restoration of the original discharge area of our rivers, as well as increasing such area at points where it originally was contracted, so that it can take care of our present flood-waters, is, of course, also out of the question, but some improvements can be made in that direction, even in the face

of the industrial developments along our rivers and with the assistance of storage reservoirs and reforestration, the stages of our floods can be reduced and the damage resulting therefrom minimized.

Thus we see that it is not a question of controlling and regulating the flood-waters of our rivers solely by one or the other of the possible methods, but rather a combination of all of them, resulting in more or less complete control and regulation, depending upon the extent to which conditions and our means permit us to employ such methods.

The storing of our flood-waters is, of course, the best means of control and regulation, because by doing so we incidentally attain other (to us) useful ends, as pointed out by Mr. Knowles, namely: First, we will have water supplies that can be let out periodically and at will, serving the purpose of maintaining navigation in our rivers at times when the natural water stage is low. Of course, the more water stored, the more we can extend the period of navigation, and thus perhaps have navigation all the year round; second, this stored water can be utilized for water supplies to our cities and boroughs, supplementing the natural supply in dry season; third, we can let out such stored water at will, when necessary for the sanitation of our water courses, instead of having an excess at some times and long periods of low stage of water, when the banks of our streams, as well as the streams themselves become seriously polluted.

Having thus gained more or less control of the flood-waters of our rivers by the above means, the second division of the subject does not become such a formidable matter, as it would be if the flood-waters were unharnessed and we were obliged to protect our cities and boroughs against the full stage of floods.

The stage of floods being lower than heretofore, the raising of our low lands or the building of quays around our river fronts need not be carried out to such extreme heights, nor do we need to put them so far back from our low water shores, although the further back the better, so as to have as much

discharge area as possible and have it come as near to the original discharge area of our streams as conditions will permit.

The arguments against building such quays or walls are again based upon the difficulties encountered in doing so, but I see no impossibilities, especially when we bear in mind that it has been done in other parts of the world, and what can be done elsewhere, we can do also. Other parts of the world have reclaimed their forests and we can do so as well, both for the retardation of the run-off and for timber purposes. Storage reservoirs for water supplies, canal purposes and irrigation purposes are by no means a new thing, and are possible on the head-waters of our streams as well.

This matter is so large and affects so many communities and so many interests aside from Pittsburgh itself that the first remedies should be inaugurated by the general government, when it becomes easier for the communities to protect themselves against whatever remains of our floods.

So much for the subject in general, now a few words about the retardation of the run-off of flood-waters by forests.

I was, the same as Mr. Morse, simply thunder-struck when I read the statement in Colonel Roberts' paper, that "forest or no forests did not affect our floods." I do not question Colonel Roberts' authority, but it surely runs counter to all our observations of the matter, to say that forests do not retard the run-off. In this connection I may tell of one of my personal observations. When building a bridge east of the mountains, over the Tuscarora Creek, about two miles from its mouth, where the mountains run in straight parallel lines, being high and narrow and the valleys narrow and deep, a very old and beautiful tree was found located along the road directly in the new abutment, and on which was found a good many notches, with the dates cut in adjoining said notches. This bridge was to replace a bridge recently destroyed by a flood in said creek and had to be made with a wider opening and at greater height. The bridge at this place

had been destroyed several times in the last seventy-five or eighty-five years, and each time the bridge had been reconstructed with a wider waterway. When studying the above-mentioned notches and dates, running back about eighty years, according to my present recollection, a very old gentleman appeared on the scene. He inquired if I knew what the notches and dates meant, and on my reply that they evidently were flood marks, he confirmed this assumption. On my inquiry as to his recollection as to what caused the floods in the recorded years, his answer was that they occurred regularly when the Legislature had passed acts, making additional lengths of the stream navigable. Please note that in former times the streams through Pennsylvania had to be declared navigable before the logging-out of the timber was permitted and, consequently, whenever a piece of timber higher up the stream was to be marketed, an additional section of the stream had to be declared navigable. The old gentleman mentioned the names of the owners of the timber land, which was cut out shortly before the recorded dates of each flood, thus accounting for the increased height of floods coincident with the cutting out of the forests on this stream. I afterwards took occasion to look up the records of this stream and the Acts of Assembly, which had declared this stream navigable. There was found to be a remarkable coincidence between such Acts of Assembly and the recorded flood years, the floods occurring regularly a few years after said Acts.

Chester B. Albree: I have been very much interested in what I have heard tonight. It seems to me that something I heard over in Tunis might be of interest. Tunis at one time, according to Roman writers, was known as the granary of Europe, that is, the place from which the great supply of grain and food and corn came to Italy. Today Tunis is practically a desert land. Certain portions of it, by means of irrigation, are of use in raising olives and a few other things, but the country is practically a desert. In the past the country was thoroughly populated. There are the remains of some

very large cities. Some cities, notably Timgad, were quite as large as Pompeii. Today we find absolutely nothing there and no reason to suppose that any one should ever want to live there. And all through the country are the ruins of very beautiful palaces. And we have the written records of what a fertile country it was. Today it is an absolute desert. Why? Because not a tree of any kind except a few olive trees exist in that entire land. Here we have a record existing, not a hundred years but a thousand, eighteen hundred; twenty-five hundred even; for the Phoenicians lived there before the Romans did. That country has been denuded of its forests absolutely and today we have desert land. We have there the records of over two thousand years as against fifty or a hundred in Pennsylvania. And if you read you will find that in Assyria the same thing occurred. It was once a very fertile country. Today the cities are buried under forty or fifty feet of sand. Why? Because the forests were completely exhausted. What do we conclude as applying to our situation? Obviously that as we denude the watershed of our rivers we gradually decrease the permanent supply of water retained there. And when we have a flood season, because we have the rains just the same, it comes down our rivers all at once, whether it be in winter or in summer; for we have floods in spring and summer when there is no frost.

We have to consider, first, the cause; then, second, the result; and third, the remedy. The causes may be summed up under two classes, one climatic changes, the other physical changes. Climatic changes we know very little about. I just finished reading an article in the Geographical Magazine stating that they had established an observatory near Washington to study the effects of the sun on our climate, and they had discovered certain apparent effects, but at the present time the connection was not at all definite. So that we can perhaps say that at the present time we do not know what the changes of the sun have to do with our climate; and as far as our records go the climate has changed very little on the earth. That brings us to the physical changes; and the only

physical change we know of is the denudation of the country by cutting off the forests. Then we come down to the effects. The effects are obvious; we have floods.

Now comes the question of remedies. If we have the floods what remedies can we apply? We may apply reservoirs or we may dam up the city so the water cannot run in. Either way reminds me somewhat of the man who drinks too much. If he drinks a great deal he has jim-jams or dyspepsia. Then the question is what remedy shall we give him if he has jim-jams and what remedy shall we give him if he has dyspepsia. That is not the scientific way. The scientific way is to get at the cause and cure the trouble. It seems to me that the only way to get at the cause is to stop the denudation of our forests.

Emil Gerber: I was somewhat surprised at Colonel Roberts' statement that the records of Germany do not show that the denudation of forests has any effect on flood-water. At the same time it agrees entirely with my own opinion that there is nothing in the denudation of forests causing high floods. The general theory that has been advanced in the argument is that the forest waters cannot evaporate as readily and are held by the humus more readily, than in open ground, and therefore floods are prevented.

Our greatest floods generally come in February or March when the ground is frozen and even the forests cannot absorb much, if any, water, and it is also at the time when if there is any snow on the ground and the sun gets at it there is practically nothing to prevent the melting of that snow unless it be in a pine forest. Most of the headwaters of our rivers are forested with deciduous timber, so that there will be at least a large portion of that area accessible to the sun during the early spring, and the ground being frozen there is no reason why the water should not get away as rapidly as if the land was bare. The flood of last March was practically from local causes. Absence of forests had very little to do with it. The causes were all to be located within 75 miles of Pittsburgh,

and even if we had forests I do not believe affairs would have been materially different, as there was little snow, we having had rain a week or so before the flood, then freezing weather and more rain.

When the ground is thawed and trees in leaf there is no doubt that there is a great deal of benefit to be derived from forests in the way of keeping up the regular flow of water.

About narrowing up the channels in our western rivers, probably for navigation purposes, the government engineers have directly recommended the narrowing up of channels. While that may be for navigation purposes, they no doubt have had in mind the effect such narrowing up would have on floods, and they did not seem to fear the narrowing up very much. Of course, in those silt-bearing rivers when the volume of water is multiplied by two, there may be a small rise and a deep scour. In the Missouri River I have observed that frequently. If we had a five-foot rise we would be pretty sure to have a ten-foot scour. In rivers that are rock or clay bound to a large extent, such as the rivers are here, the narrowing up for long distances might have a pretty serious effect on raising the surface of the water in times of high water. But if these obstructions only come in spots I don't think they have very much effect on it. In the flood of March 15 I was down near Sewickley where there is a large flat which overflowed, and, I think, illustrated what took place when the river got over its banks. The ice could be seen running very rapidly in the regular channel of the stream, while it was practically stationary over the submerged flats, which indicated that the channel was not materially increased in width, but the low lands constituted a reservoir which in the way of storing might reduce the height. As long as the river is not continuously narrowed I don't believe the narrowing in spots has any very great influence on raising the height of water at flood time.

Mr. J. P. Leaf: This matter has been of very great interest to me. I agree with the gentleman who has just sat down with regard to the narrowing up of the channels. I have made

a great many observations on high waters both in cities and in the country and find during the rise of the river the current in the low lands in the flooded area, where the water is two or three feet deep, is practically dead water. Originally these rivers, the Ohio River especially, were very much deeper than they are now. At Rochester we can go 90 ft. below the bed of the river in gravel, and I have tested it above as far as Aliquippa, and the gravel is anywhere from 80 to 90 ft. thick. It seems to me that if around Pittsburgh, for instance, material was taken out of the river bed and the channel deepened, the flow of the river would be greater and the high water mark would be materially lowered.

I made some observations on the flow of the rivers above dams and to my surprise the current of the river to within a very short distance above the dam is practically the same as if there was no dam. The surface of the water and the bottom and the centre of the river has pretty nearly the same current. When you come very close to the dam the surface of the water, of course, takes a rapid current. That being the case, even if we had dams in the river and the main channel made deeper, I think it would lower the high water very materially.

As to the effect of water flowing against the bank when the river is rising, the drift and everything goes toward the centre, and the current is very much more rapid there than along the side, indicating that friction on the bank is retarding the flow. In that way the larger the friction the less the volume of water that would flow out of the channel. I think Mr. Knowles has the right idea that it would be beneficial to have large storage reservoirs, but in flood times I think the effect of the storage reservoirs would be very slight.

On this matter of denuding our land of the trees I never thought it had much effect on the water supply or the fertility of the land. I will admit that the argument of Tunis and also Palestine and Egypt and other places, at first thought, would show that taking the forests off, if ever there was any there, would have an effect. I think you will find that the lack of vegetation is due to small rainfall. For instance, our western

prairie lands in Iowa, Illinois and the Mississippi valley, never had any trees, except along the river banks. It was always a flat, marshy country. And they have the finest soil in the world. All you have to do is to plow it up and it gets dry immediately. We haven't cut any tree off of it, it never had any on; and yet it is the richest country in the world. There is no doubt but that our rivers have a great water supply. They send down enormous quantities in flood, and it seems to me that if it be practicable, the local solution of putting dykes around our flooded area and deepening the present channels would do a great deal more good than storing. And it would be very practical to deepen the channel, because I don't know of any place where this could not be done. Of course, there are some places in the channel of the river where it is rock bottom—but it is only on one side of the river, as far as I know. There is always a gravel filled channel in the valley, so we can deepen our channels, the floods that do us the most harm are the last three or four feet of water that comes above the bank. The quantity that goes down the broadened valley outside the banks does not cut much figure, because it is mostly slack water.

Mr. Albree: One point I would like to speak about that he has brought out. He thinks it is perhaps the sand of the desert blowing over the land which has interfered with its fertility. From personal observation I happen to know that the greater portion of the immense Sahara Desert is perhaps the most fertile soil known in the world today. All it requires is water. Where there are sandy regions, especially in the neighborhood of Egypt, where the sand has blown for many years in that direction, it is perhaps not fertile. Yet perhaps 90% of the Sahara Desert today requires only water to be the most fertile land in the entire world. They produce three or four crops a year, and the most wonderful crops I ever saw in my life, on these oases. Three or four hundred miles south the French have put down artesian wells and obtained immense quantities of water and have established the most fertile oasis and sold the lands off at tremendous prices.

S. A. Taylor: I have had some experience along the rivers and streams in this vicinity, and a little of my experience it might be of interest to relate. I was glad to hear Mr. Morse say the channel was deepening in the rivers, because the very reverse of that is the fact in the tributaries leading into them. Take Turtle Creek, for instance. Probably ten or twelve years ago I was engineer for the village of Turtle Creek, and in the improving of one of the streets it became necessary to conduct a small stream which ran along practically parallel with the street, in the sidewalk along one side of the street to where it emptied into the larger stream. In a period of a little less than twelve years that stream has filled up five feet from the detritus and silt of the surrounding country. In the main stream of Turtle Creek it has filled up from two to four feet at various places. In the bed of one or two other tributaries of Turtle Creek the same thing has occurred. While a part of this filling up of the streams can be attributed to the denudation of the forests on the land tributary to these small streams, I believe there are other reasons for it as well. The physical condition of the country is changing. Town sites are being laid off, streets improved and buildings erected, and we might consider this condition applying to the entire distance affected by the late flood of some fifty or seventy-five miles up the Monongahela River. The increase of new towns, the improving of streets and the building of houses has taken place with remarkable activity. The run-off of the water in this territory has been increased not only by reason of the improvement of the streets and the number of houses that have been built, but also by reason of the fact that a great portion of the land not occupied by town sites has changed in the character of the farming within the past ten years. The land which was formerly farmed by the ordinary methods of farming, with the rotation of crops, exists today only in a very small portion of the territory within a radius probably of twenty miles from Pittsburgh, and in lieu of the old practice the land is now given over to gardening; and while the soil is more loose and fertile it is also more liable to be washed off by

heavy rains than it was under former methods of tillage, carried and deposited lower down.

The point which Mr. Knowles makes of the regulation of the streams can be readily understood by any person who has had experience with impounding reservoirs on the streams in this section. I have in mind one such reservoir which I built for a water works some six years ago and while it regulates the flow of water to some extent, it catches this silting and stops it and allows it to settle to the bottom of the reservoir until it has been filled with this material to an average depth of 3½ to 4 feet.

I know of three or four other reservoirs with which we have had similar experience. It seems clear to my mind that if dams were built on the small tributaries of these larger streams, which could be done at a very moderate cost, a great deal of the material which is now washed into our streams would be caught and kept back, while the flow in the main stream would not be affected by this fill and would to some extent at least help to prevent the rising of the flood lines in the districts affected.

Mr. Swensson: Permit me to cite a personal observation on the effect of reforestration:

The section of the west coast of Sweden, from which I hail, at the time of my boyhood was entirely denuded of forests, but many local names thereabouts indicate that the entire country was once upon a time fully forested with different species of trees. The soil there is very thin and covered an underlying rocky formation of granite. The run-off had laid much of the rock bare and the beach sand of the bays was encroaching upon the land, the prevailing winds being from the sea. As a result of these conditions, not only was the generally poor farming lands made poorer, but the question of drinking water became a serious one. The general government set about restoring habitable conditions, and, of course, the first thought was to reforest the country thereabout. However, the tree plants would not thrive and develop, owing to

scarcity of water and the encroaching of the sand. Thus the question was first to prevent the sand from cutting inland. After many trials this was accomplished by the planting of a certain weed, that by accident was discovered as being very efficient, it having been deposited near one of the harbors in sand ballast, brought over from the United States in vessels. When the sand had been put under control, it was possible to raise scrub-oak and other small trees and bushes. The matter of systematic reforestration was then taken up by the government in a systematic and unique way. As other parts of the country needed the same care in regard to the forests, a society among the public school children, known as "The Friends of the Song Birds," was organized, one part of the programme being to plant trees. This was done on a large scale, not merely in a playful manner, as at our Arbor Day, but in a more business-like way. As a school-boy I assisted in planting large acreages with trees furnished by the government, these trees having been raised from seeds on the fields of the agricultural colleges. Thirty years thereafter, on a visit to my native heath, I attended the annual meeting and picnic of this self-same society of school children in the very forest I helped to plant. At that time I noticed several refreshing springs in the woods, where in my days of childhood there had been nothing but a dry and barren waste. I judge that this was solely due to the retardation of the run-off by the forests and the retention and growth of the soil over the foundation of granite.

This is sufficient evidence to me of the value of reforestration in more ways than one.

Charles F. Scott: I have been much interested in the discussion tonight for the reason that it has opened up the general problem in a new and broad way to my mind. I never realized how many elements and how complicated is the general problem of what is considered under the name of floods before this evening. The problem is one that calls for wide scientific knowledge, accurate data, and careful analysis, to

determine the probable individual effects of many contributing causes, as well as the highest engineering talent. It seems to me that possibly not enough stress has been laid on one of the fundamental causes and that is the rainfall. For example, if we go over to the old world with Mr. Albree, he finds, as I understand, that there is not the rainfall now in certain countries that there was at one time, and he concludes that that is because there are no trees. Is there no rainfall because there are no trees, or are there no trees because there is no rainfall? Has a general climatic change of some kind, which I will not attempt to suggest, altered the rainfall and these other consequences have followed, and the forests naturally died away, so that the denudation of the forests has been the result of the change in rainfall rather than the cause? The change in the general forestration of a region can produce changes in rainfall. If waters are allowed to flow away rapidly there is a less general evaporation. I have read that in some of the desert regions out West that have been irrigated, that irrigation has produced increased evaporation and as a consequence there is rainfall, which did not exist before.

Col. Roberts: I regret that several of the speakers who have preceded me have been so wrought up at some of the theories relating to forests and floods which they attribute to me. The facts of the case are that I presented no theory, and as I have previously stated, my opinions are based altogether on records. The forest men have always the best theories at their disposal and can indulge in the most patriotic and glowing figures of speech, which almost everyone will concede ought to be true—even when recorded facts are arrayed against them.

In this discussion it ought to be made clear that we are not speaking of small streams of limited area, but applying the records to the Ohio River at Pittsburgh with a drainage area of nearly 20,000 square miles. I am ready at once to grant that with the deforesting of the country saw mills on minor tributaries cannot be operated so many months of the year as before. I will go farther and state it as my belief that ordinary

summer freshets, even on the rivers, may be higher and shorter lived than before the country was deforested, but the records do not show during the past fifty years, either at Pittsburgh or at Cincinnati, 466 miles below Pittsburgh, that the low water discharge of the Ohio is becoming less or that the great floods are more frequent and discharging more water per unit of time than formerly. In a paper prepared by myself for the American Forestry Congress, September, 1885, I took the liberty of saying, "A river of large drainage area is made up, to be sure, from a multitude of tributaries, over an area of 20,000 square miles, which is the basin of the Ohio at Pittsburgh, there are even in the seasons of the most protracted droughts almost daily thunder storms of limited area perhaps, but each deluging in turn one or more of the minor tributary valleys and causing local freshets. No rainfall may be observed at any designated station for several weeks at a time; nevertheless, the river represents the aggregate of their effect, its low water discharge being chiefly maintained by numerous miniature freshets."

During the lowest known stage of the Ohio at Pittsburgh, in 1838, at which time the country was well forested, the U. S. Engineer officer at that time engaged in making surveys, estimated the discharge of the river to be 552,000 gallons per minute, which would be equivalent to 276,000 springs in a season of drought discharging two gallons per minute, or 75 barrels each daily. During the great drought of 1895, when reports were frequent of bears, deer and other animals seeking the habitations of man for water, it is evident that the "springs of the forest" must have been "few and far between." Many wells became dry in 1895, both in this state and in West Virginia. Swamps were evaporated. In Wisconsin the small lakes declined below the level of their outlets. Chartiers Creek and many other creeks of equal drainage area became absolutely dry: yet the Ohio River, the Allegheny and the Monongahela rivers, while very low, did not reach their lowest known discharge. Now, to account for the minimum discharge of the river as in 1838, it would only be necessary that a storm covering 97 square miles daily and furnishing about one-half of an inch

run-off from such area, to make up the observed discharge. It is important, therefore, in this discussion, I urge, to separate our ideas concerning small streams of limited drainage area, and great rivers of thousands of square miles drainage areas. I am convinced that in a real dry season the water from most "perennial springs" would lose itself by evaporation in the first considerable pool it reached. And, on the other hand, our *great river floods*, as a rule, come in the springtime, when the "spongy soil of the forest," if it has been doing its duty with melted snow, etc., ought to be soaked to the maximum of its capacity; hence its efficiency in holding back much of the rainfall is not very great. There are some who argue that a ploughed field will hold back more water than the moss, ferns, roots, etc., of the beautiful forests, but that is only a theory, and as I have no theory, I will not press matters. What concerns our people most just now is not the investigation of theories of floods, but the ways and means to prevent damage from them as much as possible.

Martin Hokanson: It has been of great interest to me to listen to this discussion this evening. It seems to me there are two questions involved in this discussion; first, the protection of the City of Pittsburgh against floods; and second, the regulation of the Allegheny River. The protection of the City of Pittsburgh against floods, as has been stated before, is a local question, and can undoubtedly be solved in many ways. It is a question which would be the cheaper: to raise the lower part of the city affected, or to build retaining walls along the river to enclose the channel in connection with possible deepening of the channel. I said this was a local question, as has been stated before, the protection of Pittsburgh is only one link in the whole chain of solving the problem, and to solve the problem correctly you ought to go to the bottom of the same. Before a very thorough investigation of the whole watershed is made in regard to topography, as well as geological formation and agricultural condition of this, you

cannot determine very well how this problem to regulate the Allegheny River ought to be solved.

That the forest has a great deal to do with retarding the water is a fact, but how much we really do not know; furthermore, the forest has a great deal to do with the climatic conditions of the country. The forest serves in some way as a storage reservoir of water, and we know that a coast climate along any lake is more even throughout the year than inland climate. If the inland is overgrown with forest, this undoubtedly helps in some way to make this climate more even throughout the year, and prevents, to a certain extent, sudden heavy rainfalls which are the immediate cause for high floods. Therefore, we see that the reforesting of a country, so to say, would have a double purpose; first, to retard the water, and, second, to help to make the climate more even. As you know, the geological formation has a great deal to do with the percolation of water through the ground, forming ground water, which often does not reach the surface recipient of the watershed. The agricultural conditions also, as you all know, have a great deal to do with the evaporation and consumption of water. Certain kinds of grass sometimes absorb every drop of water which falls; others less, etc. The grass prevents the water in a similar way, from evaporation, as the woods are doing.

The topography, as I said, has a great deal to do with the maximum flow of the river, as, for instance, at the end of a narrow valley we will have a smaller maximum than at the end of a valley with the same area but of a rather circular form. All of these things have to be investigated, and before that is done, it is hard to tell how the problem can be solved. I think, though, that Mr. Knowles touched one of the vital points of the question. I think the solution of the problem would possibly be a combined one of the two, namely, reforesting of the country, and checking the different feeding lines to the river by reservoirs. If anything is going to be done in regard to protecting the City of Pittsburgh, or any other interest, it ought to be done with a view of regulating

the whole river, because the local interest is only a part of the whole thing and I am also sure that a solution of the problem as a whole will be undoubtedly considerably cheaper than the solution of the problem from a local standpoint, which, in reality, is no solution of the problem at all.

Mr. Lewis: It has been taken for granted by some of the gentlemen in the discussion, that in freezing weather the ground under a forest cover sheds water like a house roof. Now, it is well to stop and think that over. Even in deciduous timber the snow is very much better retained than in the cleared ground, and it also has the benefit of the wood-mould. And I believe if investigation was conducted it would be found that there is a very material difference between the depth of freezing under that kind of cover and the open ground. The forest retains the snow, which is in the first place a protection against freezing, while the open ground will not be protected in our climate of alternating warm and cold; and the wood-mould is about as good an insulating material as you can possibly have. And you will find that there is very light freezing under the timber canopy as compared with that of open ground.

Mr. Morse: You left out the question of leaves.

Mr. Lewis: When I say wood-mould that includes all the mould of the forest floor.

Gerald Flanagan: As related to the question of controlling flood-waters, I wish to speak rather in warning to constructing engineers regarding the erection of future structures. It would be perhaps unnecessary to add anything to what has been set before us this evening, but the human mind is so constituted that the statement of a concrete example sometimes appeals more sharply than the general discussion.

In this respect I will mention that during the recent flood I was engaged with the constructors of the Oliver power plant on the South Side; and we placed that building as we thought about two feet above any probable flood stage in the rivers.

We found, in fact, in this recent flood that the floor line was just one inch above high water; so that it looks as if it behooved future constructors of such buildings to place them even higher than what they think is necessary, provided there are not too many other drawbacks to establishing the floor lines at a higher level above record flood stage.

Edward Godfrey: I have only a few words to say about the records we have of the effects of denuded forests. If you go up almost any small stream that comes into the river, you will find the ruins of an old mill. Fifty years ago all these streams had mills along their banks. Now it takes considerable water to run one of these mills and it would not pay to put one up if it only had water a few days after a rain. Yet that is the condition today. This is evidently because of the fact that the forests have been cut at the headwaters of these streams.

The President: Unless there is some other point to be brought out, I think, on account of the lateness of the hour, it will be well to adjourn. I am sure you will all agree that we have had a very interesting discussion of a very able paper, and I wish we could have as free discussion of all the papers we are to have presented this year.

U. S. Weather Bureau Record of River Stages in the Ohio River.

Distance from Pittsburgh to Wheeling 90 miles, and from Pittsburgh to Parkersburg 183 miles.

The flood crest at Pittsburgh will reach Wheeling in about 24 hours and Parkersburg in 48 hours.

Flood stage at Pittsburgh is 22 feet, Wheeling 36 feet, and Parkersburg 36 feet.

Month	Year	Stage at Pittsburgh	Stage at Wheeling	Difference +	Parkersburg	Difference +
November 9	1810	32.0	48.0	16.0	......	......
February 10......	1832	35.0	48.1	13.1	49.5	14.5
February 1	1840	26.8	......	......	......	......
March 15	1846	25.0	......	......	......	......
February 2	1847	26.9	......	......	......	......
December 12.....	1847	24.0	......	......	......	......
December 22.....	1848	23.0	......	......	......	......
April 6	1852	25.0	......	......	......	......
April 19	1852	31.9	48.0	16.1	44.0	12.1
May 27............	1858	24.0	......	......	......	......
April 28	1859	22.0	......	......	......	......
April 12	1860	29.0	43.0	14.0	44.7	15.7
September 29...	1861	30.0	44.2	14.2	45.1	15.1
January 21........	1862	30.0	......	......	......	......
March 4...........	1862	24.0	......	......	......	......
April 22	1862	27.9	37.0	9.1	37.0	9.1
March 18.........	1865	31.4	41.0	9.6	......	......
March 13.........	1867	23.5	......	......	......	.....
December 14.....	1873	25.7	38.8	13.2	38.7	13.1
January 8..........	1874	22.2	38.8	16.4	38.8	16.4
September 19 ...	1876	25.0	......	......	......	......
January 17........	1877	24.6	......	......	......	......
December 11.....	1878	24.5	34.9	10.4	......	.....
February 11	1881	23.2	38.8	15.6	40.0	16.8
June 10............	1881	27.1	40.9	12.8	34.0	6.9
February 5	1883	24.8	39.7	14.9	45.2	20.4
February 8	1883	28 0	35.6	7.6	......	......
February 6	1884	33.3	52.6	19.3	53.9	20.6
January 17........	1885	23.0	32.9	9.9	......	......
April 7	1886	22.8	32.0	9.2	......	......
February 12	1887	22.0	33.8	11.8	......	......
February 27	1887	22.0	30.3	8.3	......	......
July 11	1888	22.0.	27.1	5.1	24.0	2.0
August 22	1888	26.0	32.2	6.2	28.5	2.5
June 1..............	1889	24.0	28.9	4.9	23.6	0.4
March 23	1890	24.3	33.0	8.7	35.0	10.7
May 24	1890	22.0	27.5	5.5	29.5	7.5
January 3.........	1891	23.2	33.7	10.5	34.5	11.3
February 18	1891	31.3	44.6	13.3	44.8	13.5
January 15........	1892	23.0	29.1	6.1	27.0	4.0
February 8	1893	24.0	34.2	10.2	38.0	14.0
February 11	1893	22.0	33.4	11.4	37.0	15.0

Record of River Stages—Continued.

Month	Year	Stage at Pittsburgh	Stage at Wheeling	Difference +	Parkers-burg	Difference +
May 22	1894	23.2	29.9	6.7	25.9	2.7
January 8	1895	25.8	36.0	10.2	37.0	11.2
July 26	1896	23.0	27.6	4.6	33.2	10.2
February 24	1897	29.5	38.8	9.3	37.9	8.4
March 24	1898	28.9	44.6	15.7	48.2	19.3
March 6	1899	22.0	28.2	6.2	29.0	7.0
November 27	1900	27.7	34.7	7.0	30.4	2.7
April 7	1901	22.1	30.0	7.9	28.5	6.4
April 21	1901	27.5	41.8	14.3	43.9	16.4
December 16	1901	25.8	34.0	8.2	28.8	3.0
March 1	1902	32.4	43.3	10.9	40.0	7.6
February 5	1903	24.0	34.6	10.6	35.0	11.0
March 1	1903	28.9	40.2	11.3	39.9	10.0
January 23	1904	30.0	44.2	14.2	42.4	12.4
March 4	1904	26.9	39.2	12.3	39.3	12.4
March 8	1904	23.2	36.3	13.1	35.0	11.8
March 22	1905	29.0	42.9	13.9	42.4	13.4
December 4	1905	23.5	31.6	8.1	29.8	6.3
January 20	1907	23.3	37.0	13.7	40.1	16.9
March 15	1907	35.5	50.1	14.6	51.6	15.1
March 20	1907	22.4	31.8	9.4	34.7	12.3

CLIMATOLOGY OF PITTSBURG, ALLEGHENY CO., PA.

Monthly and Annual Mean Temperatures.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An'l.
1871	....	42.7	47.3	56.2	64.8	73.9	71.7	73.3	59.3	54.8	38.2	29.2	
1872	27.8	30.5	30.7	52.5	62.2	70.1	75.2	73.7	65.3	51.2	35.8	24.8	50.0
1873	28.1	29.9	35.0	45.2	60.7	71.4	77.1	71.1	63.2	50.4	35.3	36.8	50.4
1874	34.9	33.9	38.5	41.8	61.4	72.7	73.6	69.3	67.2	51.9	40.1	34.7	51.7
1875	22.6	20.8	35.6	46.6	61.6	70.0	73.4	70.0	61.6	50.4	38.2	36.6	49.0
1876	37.0	36.1	36.7	48.0	61.0	73.4	77.6	74.8	63.0	49.6	42.7	23.4	51.9
1877	27.6	37.1	35.7	52.0	59.6	72.4	75.8	74.1	66.4	57.8	43.6	43.0	53.8
1878	32.1	35.8	40.4	57.2	59.8	66.9	79.5	75.2	67.0	54.5	42.4	27.0	53.6
1879 ...	20.6	27.3	41.4	48.4	63.4	69.6	76.8	72.1	62.7	61.1	43.3	38.8	52.6
1880	44.4	37.8	39.7	54.2	69.5	73.4	74.4	74.7	66.0	53.5	35.7	26.7	54.2
1881	27.6	30.0	37.1	47.2	67.2	69.4	77.0	76.0	77.2	60.0	44.9	40.9	54.5
1882	32.6	39.6	43.2	51.0	57.2	70.8	74.0	72.7	66.8	58.9	41.6	31.2	53.2
1883	28.4	34.8	34.0	50.8	61.4	71.4	74.0	70.4	63.8	55.6	46.6	36.4	52.3
1884	24.0	40.8	40.6	50.4	63.4	74.3	73.2	73.9	72.4	59.2	43.6	35.0	54.2
1885	28.2	23.6	32.0	50.2	62.6	69.6	77.6	71.9	65.6	53.2	43.6	36.2	51.2
1886	27.6	30.6	41.4	56.6	63.6	68.7	74.6	73.8	68.7	56.4	42.4	30.0	52.9
1887	31.0	38.7	37.4	51.9	68.5	71.8	80.3	71.9	*64.6	53.2	44.0	36.0	54.1
1888	28.2	34.6	37.0	50.2	61.8	71.9	72.4	72.0	61.6	49.8	45.3	35.8	51.7
1889	36.5	28.0	43.2	52.4	62.4	68.2	74.6	70.2	65.6	51.0	43.5	45.6	53.4
1890	41.4	42.0	35.8	52.6	62.0	73.5	74.0	71.1	64.6	54.2	45.4	32.1	54.1
1891	35.0	39.2	37.6	53.4	58.8	72.3	70.0	71.7	69.4	53.4	42.3	42.1	53.8
1892	28.0	36.2	34.9	50.2	61.1	74.6	73.4	73.5	66.5	54.0	41.6	31.3	52.1
1893	21.6	31.8	40.1	51.4	59.6	71.8	73.7	71.4	65.3	55.4	41.6	35.6	51.6
1894	37.0	31.7	47.4	51.0	61.6	71.6	76.2	73.6	70.4	50.4	40.4	36.6	54.5
1895	27.0	22.8	36.4	53.6	63.3	74.7	71.6	74.5	71.0	49.8	45.4	37.4	52.3
1896	31.4	32.4	33.0	57.2	69.2	70.4	73.8	72.5	65.2	50.6	48.6	35.2	53.3
1897	27.4	35.0	44.6	51.0	58.0	67.9	76.2	70.5	67.6	59.2	44.9	36.9	53.3
1898	35.3	32.3	47.8	48.5	63.2	73.8	77.2	74.9	70.2	56.0	42.7	32.9	54.6
1899	31.4	25.4	40.2	55.0	65.0	72.2	75.6	74.2	65.4	59.4	46.2	33.8	53.6
1900	34.0	29.0	34.3	52.2	64.8	72.4	76.3	78.7	72.2	62.9	45.4	34.7	54.7
1901	32.5	24.6	41.6	49.1	62.0	71.8	78.9	75.0	66.5	56.7	39.2	33.0	52.6
1902	30.4	26.7	44.2	50.5	64.5	68.4	75.4	71.0	66.2	57.6	51.2	32.2	53.2
1903	30.6	33.4	50.1	51.6	66.4	65.8	74.3	72.2	67.4	56.2	39.5	27.6	52.9
1904	25.3	25.8	41.2	46.4	64.0	70.9	72.8	70.7	67.6	54.6	43.8	31.2	51.2
1905	26.2	24.6	45.4	50.6	63.5	71.2	74.6	72.1	65.8	54.8	40.4	35.2	52.0
1906	38.4	28.9	33.8	51.4	62.2	70.8	73.4	75.6	69.6	53.4	43.2	33.2	52.8
Mean	30.8	32.1	39.5	51.1	62.8	71.2	75.0	72.9	66.6	54.9	42.6	34.1	52.9

1871 to 1874 from means of tri-daily observations. * For 29 days.

Average number of days with maximum 32° or below. and 90° or above.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An'l.
32° —	10	8	3	0	0	0	0	0	0	0	2	8	31
90° +	0	0	0	0	1	4	8	5	2	0	0	0	20

Average number of days with minimum 32° or below, and zero or below.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
32° —	23	21	18	4	0	0	0	0	0	1	11	21	99
zero..	1	1	0	0	0	0	0	0	0	0	0	0	2

Maximum Temperatures.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An'l.
1874	......	......	......	......	......	......	......	......	......	......	......	......	......
1875	51	70	79	82	93	95	95	88	92	77	62	69	95
1876	70	69	80	84	91	95	101	96	88	80	79	51	101
1877	53	66	67	80	93	90	96	94	87	84	65	67	96
1878	57	60	74	88	85	96	101	94	88	84	62	52	101
1879	54	54	77	82	93	94	99	93	90	91	76	61	99
1880	67	72	69	84	94	97	96	98	92	81	70	69	98
1881	52	63	61	86	95	90	103	100	102	89	76	67	103
1882	61	60	75	83	82	97	93	91	91	81	74	50	97
1883	54	77	69	86	90	90	90	94	93	86	73	64	90
1884	53	70	71	78	92	95	97	98	100	92	70	67	100
1885	60	52	61	89	87	94	99	95	87	82	72	73	99
1886	61	63	77	85	89	92	96	93	92	79	69	58	96
1887	68	67	68	84	95	94	101	93	92	80	74	62	101.
1888	61	61	72	86	85	95	90	93	81	74	74	62	95
1889	61	53	70	83	90	87	93	89	90	75	69	67	93
1890	71	68	68	78	86	92	94	91	89	78	73	52	94
1891	57	68	65	81	84	92	89	94	90	85	76	63	94
1892	60	62	61	79	88	92	96	93	86	78	72	70	96
1893	57	59	73	80	85	91	95	92	88	86	68	64	95
1894	60	64	76	82	87	95	97	93	92	82	74	62	97
1895	58	60	63	82	93	98	90	95	94	73	74	67	98
1896	56	65	68	90	90	89	93	94	92	79	74	60	94
1897	63	61	70	81*	81	88	99	91	96	87	69	65	99
1898	67	70	78	78	86	92	99	92	94	80	70	65	99
1899	66	60	71	88	86	93	95	96	92	86	68	65	96
1900	59	77	62	80	92	94	96	98	97	89	74	61	98
1901	59	48	76	83	86	94	98	93	87	81	70	71	98
1902	52	64	74	86	91	90	93	90	86	76	73	60	93
1903	64	62	78	83	88	85	92	94	90	88	69	54	94
1904	66	61	78	70	91	90	90	90	88	82	68	70	91
1905	57	44	82	77	88	92	93	91	86	70	61	58	93
1906	75	70	65	80	86	80	88	90	90	78	75	61	90
Extr'ms	75	77	82	90	95	98	103	100	102	91	79	73	103

Minimum Temperatures.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An'l.
1874	......	......	......	......	......	......	......	......	......	......	......	......	......
1875	-12	-10	11	14	34	43	57	51	36	31	8	1	-12
1876	7	6	8	27	27	50	54	49	44	25	22	-6	6
1877	4	15	2	25	33	47	53	53	42	38	14	20	2
1878	-1	9	16	35	34	43	57	52	41	28	24	4	-1
1879	-12	4	19	23	33	39	56	50	35	29	16	6	-12
1880	20	10	18	26	35	49	53	51	39	30	4	-9	-9
1881	3	-4	19	17	38	50	57	54	51	35	18	15	-4
1882	2	20	22	22	34	46	54	51	47	36	22	-2	-2
1883	1	13	11	26	39	48	54	52	39	34	15	15	1
1884	-6	-3	10	30	39	50	52	52	44	29	19	-2	-6
1885	2	-9	5	25	39	46	50	47	43	34	21	6	-9
1886	-5	-3	11	30	41	45	54	52	48	36	22	7	-5
1887	4	15	15	24	47	52	60	46	36	20	14	8	4
1888	3	1	9	26	37	41	50	48	39	33	24	12	1
1889	17	-1	23	25	37	46	56	50	44	30	20	22	-1
1890	11	10	5	28	37	47	53	45	40	35	23	16	5
1891	18	9	11	24	34	50	52	48	46	31	16	16	9
1892	2	12	13	27	36	56	53	56	46	33	18	3	2
1893	-3	2	13	32	38	52	53	50	35	29	16	15	-3
1894	10	6	15	24	40	42	49	51	43	34	22	-4	-4
1895	-5	-6	16	28	35	50	50	52	42	27	22	13	-5
1896	-2	-2	9	22	50	47	53	50	39	30	19	11	-2
1897	-7	8	24	26	37	42	59	50	38	38	19	9	-7
1898	10	0	20	20	40	55	51	56	48	32	18	8	0
1899	5	-20	13	25	42	47	55	55	39	30	28	5	-20
1900	2	-4	1	25	33	54	52	54	47	30	20	11	-4
1901	10	7	2	31	42	45	58	58	45	31	23	4	2
1902	8	2	12	29	37	49	56	51	44	37	24	11	2
1903	2	-3	25	24	36	48	54	54	42	32	17	6	-3
1904	-2	-5	17	23	41	53	54	49	39	30	20	6	-5
1905	0	-7	15	27	38	48	58	51	42	34	18	16	-7
1906	11	-3	12	25	33	49	57	53	50	28	27	9	-3
Extr'ms	-12	-20	1	14	27	39	49	45	35	20	4	-9	-20

Monthly and Annual Precipitation.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	An'l.
1871	....	2.64	1.03	2.04	0.98	4.77	3.24	5.65	1.56	2.66	3.30	1.25	......
1872	1.85	1.03	1.38	1.09	2.66	2.69	7.71	2.79	2.57	4.11	0.83	2.88	31.59
1873	3.16	3.08	3.87	3.04	3.21	2.15	3.44	5.19	1.94	6.21	1.72	3.46	40.47
1874	2.92	3.15	2.94	7.20	2.37	1.84	7.68	1.98	2.56	0.06	3.36	3.30	39.36
1875	2.17	1.57	3.45	2.07	2.79	2.85	5.27	2.19	2.56	2.36	2.96	3.79	34.03
1876	3.59	2.83	5.80	2.04	3.35	1.47	5.86	2.72	7.35	1.14	2.03	0.83	37.01
1877	2.99	1.43	5.31	2.88	1.66	3.54	3.98	2.10	1.90	2.76	4.48	1.69	34.72
1878	2.52	1.14	2.42	2.60	1.76	5.18	5.15	1.29	5.55	2.99	4.20	3.96	38.76
1879	1.54	1.74	2.99	1.63	1.20	4.56	7.78	5.56	1.01	0.65	3.36	5.00	37.02
1880	3.02	2.63	2.87	2.41	1.25	3.52	2.15	3.62	3.12	2.80	1.73	2.95	32.07
1881	3.55	3.45	3.35	1.81	2.34	6.95	3.86	0.88	0.76	3.75	2.66	3.94	37.30
1882	4.58	3.14	3.78	1.39	5.80	4.14	1.99	4.50	4.08	1.74	2.07	1.42	38.63
1883	3.22	4.92	2.51	3.69	5.38	4.73	5.52	3.40	2.47	2.43	1.50	3.40	43.17
1884	4.82	4.57	3.71	1.11	3.48	1.71	4.04	2.94	1.17	2.01	1.18	4.07	34.81
1885	4.03	1.90	1.14	2.79	3.26	2.66	2.49	5.64	1.69	4.29	2.57	1.64	34.10
1886	3.21	1.39	2.85	4.02	3.50	5.17	5.55	2.85	2.86	1.06	4.91	1.81	39.18
1887	1.92	6.52	1.49	4.29	5.78	4.50	9.51	2.16	2.03	0.39	1.37	1.99	41.95
1888	6.17	1.74	2.51	1.04	4.13	2.22	4.36	7.26	1.77	3.46	3.57	1.66	39.89
1889	2.50	1.58	2.32	3.62	6.45	4.93	5.48	1.88	2.87	2.06	4.61	3.07	41.37
1890	4.18	5.52	3.86	4.87	5.85	3.37	2.22	4.06	4.24	5.66	1.14	5.64	50.61
1891	2.43	6.09	3.11	1.18	3.23	3.90	7.65	1.60	1.90	1.53	2.61	3.05	38.28
1892	3.29	1.85	2.29	2.93	3.77	4.15	5.88	2.22	2.04	0.51	1.81	1.92	32.66
1893	2.36	4.74	1.17	4.94	4.50	2.87	5.08	2.94	1.86	3.22	1.46	2.70	37.84
1894	2.02	2.98	2.41	3.63	4.63	0.61	1.16	0.43	3.68	1.72	1.80	3.10	28.17
1895	4.16	0.77	1.73	1.83	1.97	2.26	2.11	4.29	1.83	1.11	2.24	3.20	27.50
1896	1.63	2.89	4.13	3.39	3.91	4.79	8.96	4.09	4.17	2.26	2.76	1.37	44.35
1897	1.34	4.30	3.50	3.34	2.70	2.97	4.52	2.08	1.65	0.13	5.11	3.44	35.08
1898	3.40	1.60	5.45	1.60	3.99	3.98	2.56	4.09	1.06	3.85	2.34	1.92	35.76
1899	3.41	2.68	3.37	2.59	3.26	3.72	3.13	2.57	2.66	2.10	2.12	2.24	33.85
1900	1.54	2.86	2.35	1.25	1.34	3.25	3.42	0.84	1.01	2.24	3.64	1.99	25.73
1901	1.98	0.91	3.69	8.11	5.60	4.41	2.84	4.04	1.96	0.38	1.80	4.84	40.76
1902	1.49	1.45	4.15	2.70	2.30	5.79	2.94	1.61	2.21	2.79	1.08	3.71	32.22
1903	2.33	3.99	4.29	2.82	1.67	5.27	5.66	4.71	1.04	2.88	2.60	1.55	38.81
1904	2.51	2.00	5.11	3.02	3.48	5.76	2.72	2.36	2.35	2.09	0.22	2.34	33.76
1905	2.36	1.41	3.03	2.07	2.79	6.64	3.01	3.11	2.41	3.58	1.80	3.02	35.19
1906	1.84	1.09	3.85	1.70	2.08	4.08	4.18	2.96	3.10	2.94	0.95	2.52	31.29
Means..	2.85	2.71	3.09	2.85	3.30	3.82	4.53	3.13	2.47	2.39	2.44	2.80	36.38

Greatest Precipitation in 24 Consecutive Hours.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l.
1871	....	0.48	0.52	1.03	0.50	1.36	0.64	2.92	0.93	1.15	1.85	0.65	2.92
1872	0.65	0.44	0.40	0.25	1.01	0.62	1.81	1.06	1.31	1.90	0.28	0.55	1.90
1873	0.68	0.89	0.92	0.59	1.34	0.63	1.05	2.03	1.05	1.98	0.77	0.95	2.03
1874	0.90	1.39	1.39	1.46	0.74	0.43	3.40	1.00	0.86	0.03	0.75	1.65	3.40
1875	0.54	0.49	0.92	0.66	0.52	1.10	1.21	0.77	0.55	0.76	1.03	1.13	1.21
1876	0.73	0.55	1.12	0.55	1.08	0.56	1.19	1.81	4.08	0.20	0.43	0.21	4.08
1877	0.92	0.65	1.32	1.58	0.64	0.79	1.60	0.66	1.17	1.31	1.69	0.70	1.69
1878	0.96	0.30	0.73	0.65	0.51	1.37	2.80	0.81	3.88	1.45	1.30	1.20	3.88
1879	0.61	0.52	0.53	0.78	0.62	0.97	1.47	2.59	0.35	0.29	0.40	0.96	2.59
1880	0.81	1.18	0.86	0.85	0.84	0.86	0.99	1.30	1.19	0.99	0.71	0.84	1.30
1881	1.29	0.84	1.10	0.53	1.11	2.52	0.98	0.79	0.33	0.69	1.07	0.86	2.52
1882	0.65	0.64	0.91	0.56	0.97	1.44	0.49	1.21	0.93	0.88	0.47	0.26	1.44
1883	0.74	1.35	1.01	1.04	1.30	1.23	1.44	1.84	0.78	0.87	0.29	1.47	1.84
1884	2.34	1.11	0.69	0.56	0.85	0.67	1.41	1.94	0.62	0.53	0.31	0.97	2.34
1885	1.24	0.52	0.31	0.74	1.26	1.47	0.80	2.61	0.96	1.32	0.99	0.58	2.61
1886	0.85	0.46	0.67	2.38	1.03	1.76	2.10	1.05	1.30	0.37	1.12	0.57	2.38
1887	0.59	2.01	0.32	2.56	2.25	1.64	3.85	0.79	0.85	0.20	0.67	0.80	3.85
1888	1.21	0.63	0.55	0.25	1.01	1.11	1.10	3.65	0.96	0.69	0.66	0.58	3.65
1889	0.74	0.67	0.96	0.95	2.96	1.75	1.45	0.86	1.40	0.64	1.11	0.87	2.96
1890	1.46	1.69	0.82	1.40	0.83	1.24	0.74	0.96	1.58	1.91	0.24	2.35	2.35
1891	0.64	1.64	0.79	0.49	0.96	1.08	1.69	0.54	0.58	1.00	0.70	1.01	1.69
1892	1.32	0.48	0.46	1.18	0.70	1.05	2.16	0.68	0.60	0.19	0.46	0.90	2.16
1893	0.52	0.78	0.22	0.83	1.28	1.08	1.29	2.16	0.72	1.27	0.64	0.95	2.16
1894	0.50	0.63	0.71	1.10	0.91	0.29	0.56	0.37	1.44	0.62	0.44	0.88	1.44
1895	1.18	0.30	0.34	0.66	0.56	0.84	0.54	1.47	1.12	0.57	0.68	1.04	1.47
1896	0.77	0.56	1.14	1.27	1.02	1.22	2.31	2.31	1.70	1.03	0.69	0.60	2.31
1897	0.29	1.46	0.85	1.08	1.22	1.38	1.23	0.43	0.52	0.12	1.19	1.17	1.46
1898	0.67	0.74	2.04	0.61	1.18	1.35	0.96	1.02	0.42	1.55	1.00	0.65	2.04
1899	1.16	0.54	0.80	1.27	1.52	1.02	0.83	0.84	1.02	1.68	0.74	0.74	1.68
1900	0.50	0.67	0.67	0.51	0.42	1.08	1.06	0.28	0.26	1.08	1.35	1.41	1.41
1901	0.45	0.24	0.98	2.60	1.15	1.10	0.79	1.44	0.62	0.16	0.87	2.44	2.60
1902	0.37	0.48	1.50	1.27	0.59	1.12	0.66	0.59	0.53	1.14	0.30	0.69	1.50
1903	0.56	0.98	1.22	0.83	0.71	1.46	1.54	2.22	0.43	1.05	1.53	0.72	2.22
1904	0.77	0.72	1.66	0.89	0.95	2.03	0.71	0.57	0.64	1.04	0.11	0.64	2.03
1905	0.99	0.37	1.08	0.52	1.01	1.66	0.91	1.27	1.63	0.91	1.04	1.52	1.66
1906	0.70	0.36	0.89	0.55	0.63	1.83	2.38	0.71	2.34	1.61	0.33	0.62	2.38
Greatest	2.34	2.01	2.04	2.60	2.96	2.52	3.85	3.65	4.08	1.98	1.85	2.44	3.85

Monthly and Annual Snowfall (unmelted) in inches and tenths.

Year.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1885.....	6.4	14.2	7.5	4.1	T.	0	0	0	0	T.	2.4	5.3	39.9
1886.....	22.0	2.4	2.0	5.4	0	0	0	0	0	0	1.9	4.4	38.1
1887.....	8.7	9.1	4.1	T.	0	0	0	0	0	T.	1.6	6.0	29.5
1888.....	9.4	2.2	1.8	T.	0	0	0	0	0	T.	3.0	2.3	16.7
1889.....	5.4	5.7	5.2	7.0	0	0	0	0	0	T.	0.3	0	23.6
1890.....	T.	2.1	8.9	T.	0	0	0	0	0	T.	T.	41.3	52.4
1891.....	3.2	2.3	7.6	2.0	0	0	0	0	0	T.	2.9	0.4	18.4
1892.....	8.8	3.6	12.0	0.4	T.	0	0	0	0	T.	2.0	3.5	30.3
1893.....	15.2	18.3	2.8	0.5	T.	0	0	0	0	T.	0.6	4.0	41.4
1894.....	1.8	20.5	3.1	T.	0	0	0	0	0	T.	0.3	13.1	38.8
1895.....	8.3	5.0	7.6	0.2	T.	0	0	0	T.	0	0.4	3.1	24.6
1896.....	0.7	6.7	17.0	0.4	0	0	0	0	0	0	T.	3.2	28.0
1897.....	10.6	3.8	2.2	0.1	0	0	0	0	0	T.	0.2	10.4	27.3
1898.....	3.9	3.1	2.4	2.2	0	0	0	0	0	T.	2.8	6.7	21.1
1899.....	19.2	14.5	5.2	0.2	0	0	0	0	0	0	0	1.0	40.7
1900.....	2.5	9.6	8.5	0.5	0	0	0	0	0	0	4.7	7.7	33.5
1901.....	6.4	5.7	5.8	13.5	0	0	0	0	0	0	3.0	10.2	44.6
1902.....	10.7	3.5	16.7	12.1	0	0	0	0	0	0	2.1	10.6	55.7
1903.....	6.1	7.2	T.	T.	0	0	0	0	0	0	1.0	8.5	22.8
1904.....	6.6	4.5	0.4	1.3	0	0	0	0	0	0	0.1	8.4	21.3
1905.....	17.2	5.2	2.5	0.7	0	0	0	0	0	0	T.	2.0	27.6
1906.....	3.5	4.9	20.1	T.	T.	0	0	0	0	T.	2.5	7.4	38.4
Means..	8.0	7.0	6.5	2.3	T.	0	0	0	T.	T.	1.5	7.3	32.6

Precipitation at the Rate of One Inch per Hour and Over.

Year	Date	Amount
1871,	None.	
1872,	None.	
1873,	None.	
1874,	July 7	1.01
1874,	July 26	1.02
1874,	August 12	1.00
1875,	None.	
1876,	July 20	1.08
1877,	None.	
1878,	July 4	2.50
1879,	None.	
1880,	None.	
1881,	None.	
1882,	June 16	1.44
1883,	None.	
1884,	August 16	1.85
1885,	None.	
1886,	July 26	1.50
1887,	July 9	1.22
1888,	None.	
1889,	None.	
1890,	June 15	1.15
1890,	October 13	1.00
1891,	None.	
1892,	None.	
1893,	May 20	1.01
1893,	July 26	1.00
1894,	None.	
1895,	September 10	1.11
1896,	May 13	1.00
1896,	July 15	1.45
1896,	August 13	1.70
1897,	None.	
1898,	None.	
1899,	None.	
1900,	None.	
1901,	June 22	1.00
1902,	None.	
1903,	July 4	1.33
1904,	None.	
1905,	None.	
1906,	None.	

Before the Mechanical Section, June 4th, 1907.

Sumner B. Ely, Chairman.

In the Chair.

Vanadium Steel.

BY J. KENT SMITH,

Non-Member.

Chairman Ely: I remember six or seven years ago being at the Bethlehem Steel Co., when some one was making experiments with an alloy of steel, and he told me they had a piece of vanadium steel which showed some very remarkable results. He said the trouble was they could not get the vanadium. We have tonight with us Mr. J. Kent Smith, who is very familiar with this subject. We will be very glad to hear from him.

J. Kent Smith: Mr. Chairman and Gentlemen—I am very much obliged to you for the honor you have accorded me in asking me to address you on this subject, upon which I propose to let my lecture take the form of somewhat general remarks, as it would be impossible for me to deal at length tonight with any one detail of so wide a question.

About the first query generally put to one is, "What is vanadium?" I need hardly say that vanadium is a true chemical element. It is one of the seventy odd elements which compose the formation of the crust of this globe. While it is a true metal, at the same time it is on the borderland of the metals, so to speak, and also acts as a metalloid, (as do aluminum, manganese, chromium, etc., oxidized compounds of which may act as acid radicles, and so assist in forming salts). Tonight, of course, we discuss vanadium only from its metallic point of view.

Vanadium is often spoken of as a recent discovery. As a matter of fact, vanadium as a separate entity was discovered about 107 years ago by Del Rio. He discovered a strange

body, and out of deference to the fact that he had isolated it in a reddish compound, he christened the substance erythronium. His brother chemists told him that it was not a new element but was really chronium, which had already been discovered for some thirty years. About 30 years afterwards Sefstrom, working on some Swedish ores, discovered a reddish brown oxide, and on investigation it turned out that this was really a compound containing Del Rio's element and that the work done by this chemist was perfectly correct. After one of the deities—the "Earth Mother"—of the country from which the ore came, Sefstrom called the metal vanadium; and judging from the enormous power for doing good possessed by it, the name perhaps is really more appropriate than was thought at the time.

Again, we hear people say that vanadium is a rare element. This, too, is a misnomer, because vanadium is by no means rare, but on the contrary, is very widely distributed indeed. Soap contains appreciable quantities of vanadium, because commercial caustic soda contains vanadium. But as the soap contains about 8 to 10% of caustic soda and as the caustic soda contains, say, .004% of vanadium, soap could hardly be considered a very profitable source from which to extract vanadium. Ordinary fire clay contains small quantities of vanadium; the ordinary red clay from which flower pots are made contains sometimes quite notable quantities. In view of all this, it would not be quite correct to say that vanadium is a rare element.

In fact, some of the popular ideas regarding vanadium very much remind me of an instance I quoted the other night to a number of friends. A man was compiling a dictionary and in that compilation he defined a crab as a "little red animal that walked backwards." The editor of the dictionary submitted the definition to an eminent natural scientist and asked him what he thought of it. He said, "A crab is not always little, is not red, certainly is not an animal, and does not walk backwards. In all other respects the definition is perfectly correct."

Vanadium is rare in the sense that it is very seldom found in quantity in such a concentrated form as to repay the cost of its extraction. A little time ago our sources of vanadium were comparatively lean ores, containing perhaps one or two per cent of the oxide of the metal, and even those deposits were fairly limited in extent. But a new phase altogether has been put on the question by the discovery and development by a firm in this city of large deposits of vanadium in South America, of such a kind as were heretofore not suspected to exist, either by the mineralogist or the metallurgist. The ore itself is a natural sulphide containing about 35% (sometimes 40%) of sulphide of vanadium, free sulphur, sandy gangue, and a small proportion of other innocuous oxides. By simply roasting, the ore loses 45% of its weight and the residuum contains from 50 to 60% of the oxide of vanadium. As the quantities of the ore in sight are enormous and the quantities on the property which have not been as yet brought to actual sight are known to be still greater, we can safely say that today the element is no longer rare, and that we have a supply of the metal which is amply sufficient for all possible needs for very many years to come.

The metal itself is a silvery white body, said to have a gravity of 5.6 and a very high fusing point. This fusing point is said to be 2000°C., but when it comes to a question of taking those high temperatures we have to accept many published figures with a certain amount of reservation, because the tendency in high temperatures is to exaggerate. This we do know, that the melting point of pure vanadium is considerably higher than that of platinum. While platinum has been recorded as melting at nearly 2000°C., it melts, as a matter of fact, somewhere above 1700°C. At any rate, as a practical proposition pure vanadium does not concern us very much, except as a "refractory," say in the filaments of incandescent lamps, etc. The metal itself could not be used in the steel making industry, party because of its high fusing point, and that is the use that interests us most tonight. But the observed fact that an alloy of approximately two parts or iron

to one of vanadium has a melting point very much lower than that of ordinary steel at once changes the aspect of things. There is no difficulty whatever in applying such ferro vanadium to molten steel and getting a thorough incorporation with complete ease of handling, economically and commercially.

The observed effects of the element on steel without doubt mark an epoch, and these extraordinary effects are not mere matters of theory, or of one or two laboratory experiments, but are proved by unimpeachably demonstrated facts. Vanadium steels have been in use and have demonstrated their great value for the last five years.

After all, one of our best authorities has said that there is nothing new under the sun, and the application of vanadium to steel is only following the dictates of nature, because it is a notable fact that some Swedish steels which are remarkable for their extreme vitality under trying conditions contain notable quantities of vanadium, and those Swedish steels which are the best generally contain the most vanadium, other things, of course, being equal, as vanadium is a powerful "tonic," but not an "antidote."

Before alluding in detail to particular vanadium steels, I should very much like to speak a few minutes on the question of steels in general. I think we have all now come to the well established conclusion that there is something else to be looked for in steel besides good behavior under ordinary static stresses. Because steel will bend under a steadily applied load, will bear a considerable steadily applied load without breaking, and will stretch nicely before it breaks, it by no means follows that when stresses are put on the steel in a totally different manner the metal will behave equally well. In average steel there is often a certain coincidence between behavior under static load and under dynamic stresses, but the coincidence is by no means universal, and it is particularly in those cases where it is not universal that we have been accustomed to get our "mysterious failures." I believe it is beyond argument that it is possible to break a steel by a re-

peated application of stresses that are far below its elastic limit. Some steels will break more easily than others, and all steels will break in the end, by what we know as "progressive fracture," perhaps the most dreaded and certainly the most common form of fracture in service. In it we have no elongation and no reduction of area, but still we have a fracture. It is not a question of want of resistance to purely static stresses, or of breaking the steel with a blow, but rather of "wearing that steel out"—not abrasively but as a human being gets worn out after he has done a certain amount of work. If you can impregnate steel with vitality, if you do not merely make it initially stronger, but give it more endurance, then you have accomplished the main thing necessary. Under present conditions of engineering, it is beyond doubt that a very large amount of our failures are due not so much to initial static wants, as to some form of fatigue, and vanadium has been proved to be pre-eminent among alloys in the property of endowing steels with the property of resisting fatigue.

We talk about steels of a certain "complete analysis," but the so-called complete analysis is after all very incomplete. We do not reckon in it the estimation of elements which here are most dangerous. There is no doubt one of the commonest of such is oxygen, a terribly mischievous thing in the wrong place. I firmly believe that in fairly "easy" service many steels fail chiefly on account of their oxygen contents; for I have never yet found steel oxidized in the furnace to stand repeated strains as well as properly finished steel.

I have spoken of the dynamic attributes of steel and the deterioration of steel by fatigue. I might give you two or three examples which show not only the great value of vanadium in resisting alternating stresses and strains, but also that the rate of deterioration is not the same in all steels. The latter is a vital question; those steels which are best fitted to withstand such deterioration are the steels that are going to be the best in service. As a comparative instance, a carefully made structural carbon steel of admittedly high quality, a

sample of very high grade "structural" nickel steel (made in Sheffield, England,) and a sample of vanadium steel were each submitted to a sweeping shock that would destroy the steel. Where the carbon steel stood 11 foot-pounds the nickel steel stood 14 and the vanadium steel 17. When instead of giving a single shock it was less violent and repeated until the sample broke after a reasonable number of blows, where the carbon steel stood 25, the nickel stood 35, and the vanadium steel 69 blows. When the impact was made much lighter and repeated at an enormous rate, (on Arnold's form of testing machine), the carbon steel went 300; the nickel steel went 290—showing its fundamental inferiority even to carbon steel—the vanadium steel went 540. The conditions of the machine were next made very much less severe and the carbon steel then stood 900 before breaking, the nickel steel stood 800 and the vanadium steel stood 2700. The conditions were again made less severe still, a permanent flexion being scarcely produced, but the alternations of stress increased to 1200 a minute. The carbon steel stood 6000, the nickel steel stood 10,000 and the vanadium steel 67,000. Those figures will illustrate the great superiority of vanadium steel over carbon and nickel steels in resisting disintegration under dynamic stress. The alloy steels be it noted, were taken as having about the same tensile strength so as not to give rise to misleading comparisons, owing to the fact of the stresses applied being at very greatly differing distances from their elastic limit.

I have said that vanadium itself confers the power of resisting alternating stresses to steel, but it does more than that; it is, in fact, a "master alloy." Statically, it will enormously intensify the reaction of other constituents. It will increase per se the absolute static qualities of a dead mild steel, but in steel of .30% carbon a greater increase, and if the manganese be also raised a still greater increase, in proportion for a given amount of vanadium added, will be noted. It is a recognized thing that in the ordinary alloy steels we are almost sure to get some fundamental dynamic deterioration. True, we have raised out elastic limit and strength and

kept our ductility, but what we are giving with one hand we are to a certain extent taking back with the other, because though we have improved the steel in one direction, if we have dynamically deteriorated it we have negatived some of the good. There are some alloy steels which are not as much better as their static tests would lead us to believe. In accordance with previous statements, vanadium intensifies another alloy so that a smaller proportion of that alloy can be used and the steel be not damaged dynamically, while the vanadium in itself greatly improves the dynamic qualities of the metal iron.

Vanadium has many beneficial effects. It deoxidizes steel. Vanadium is a very avid element for oxygen, much more so than is iron or manganese and thus vanadium under proper heat conditions will decompose oxide of iron. I do not propose that such an expensive scavenger as vanadium be used to remove oxygen, that it is in the province of the steel maker to remove by cheaper means. But vanadium insures the removal of its *last traces*, and these not as a dry oxide, but as a *fusible* oxide which easily passes through the steel into the slag. But it does something even more important than removing oxygen, in the way of cleaning, because it removes nitrogen and we know that nitrogen, even in infinitesimal quantities, is very detrimental to steel.

Without doubt, one of the main reasons why vanadium renders steel so resistant to deterioration under repeated strains, is that it toughens the constituent we call ferrite. Structural steel is by no means a homogeneous material; in it we have a background of carbonless iron, while its carbon is united *chemically* with another small proportion of iron, this carbide of iron alloys itself with yet another portion of carbonless iron, and the particles of this alloy are distributed through the main "background." Not only are the granules of vanadium ferrite (or carbonless iron) much tougher than the granules of common ferrite, but they are very much more firmly knitted together so that vanadium ferrite will, under repeated strains, stresses and impacts, not be pulled apart so

readily as if it were plain ferrite. Some ferrites are much more susceptible to deterioration than others, owing to their crystalline arrangement. This would help to account for the fact that nickel ferrite shows a less resistance to alternating impact than does even a plain ferrite.

As stated just now that it is well proved that if you put strains onto steel, the farther those strains are removed from the elastic limit the longer the steel would stand them, other things being equal. A sample of vanadium steel was sent to a well-known engineer over in the East and tested in his laboratory on a vibratory stress machine. Under the conditions adopted several samples of carbon steel stock all broke after about 20,000 revolutions. The vanadium steel endured 100,000,000 and remains unbroken. The carbon steel was ordinary structural steel, the vanadium steel had an elastic limit probably three times as great as the carbon steel, and he was testing them both under the same degree of fibre stress. In the one case the fibre stress was comparatively near the elastic limit and in the other away below it and that so accentuated the difference already detailed that these extraordinary figures were obtained. I contend that the proper form of this test is where the fibre stress is proportioned to the elastic limit; then we get at the true comparison of the material to deterioration under safe loads; and here the vanadium steel takes a rank far above all other steels.

Pearlite, that is, the alloy containing the carbon, is, as before stated, distributed in the ferrite. Where you have two separate bodies adjacent to each other there may be lines of weakness at their junction if those bodies, which have cooled down from a molten condition, have an unequal coefficient of contraction. Vanadium seems to strengthen the cohesion there as well as the cohesion of the granules of ferrite and thus makes the vanadium steels stronger and tougher.

Again we have the fact that vanadium renders ferrite more "impervious" to segregation through it. The logical conclusion is that vanadium steels would be much more benefited by tempering than ordinary steels. Tempering involves

splitting up the carbide, dissolving it in the mass, abstracting the heat suddenly so that the solid solution of carbide is frozen, and decomposing that solution, leaving the precipitated carbide "in situ" as far as possible. Under this "decomposing heat the carbides tend to resume their original form, and to colonize or segregate, the rate of segregation increasing rapidly with regular increments of temperature in the decomposing or "letting down" heat. If the medium through which this carbide has to segregate is more "impervious" to segregation, the steel is better fitted for tempering, the limits are wider and the improvement is correspondingly greater.

As regards forging: A vanadium steel forges just as well as a carbon steel. All "high temper" steels are susceptible to disintegration at high heats unless the initial heat be applied carefully, and in reasonable gradations in the beginning. Again, the quality of all steels depend a great deal on the "pit" practice in the steel works. We all know the unsatisfactory nature of steels that have been cast under certain conditions and we must consider the casting of vanadium steel just the same as we have to consider the correct casting of all classes of high grade steel. The most "fool-proof" steel is without doubt the mildest kind of steel; from that up through the high carbons steel becomes more "tender," and the ordinary alloy steels are still more "tender." When we come to drop forging, as vanadium steel flows easily in the dies it is eminently fitted for this, in striking contrast to many alloy steels. Vanadium steel may be said to drop forge like mild steel. There are drop forgers in this district which will substantiate my statement, confirming the experience of six years in Europe.

Dynamic improvement enters largely into the question of steel castings. In steel castings we use vanadium almost entirely to increase the dynamic properties of the casting. There is not much doubt that most castings fail not so much from the want of original strength, as from the fact that they do not stand the conditions of service where they are subject to rapidly changing stresses. If we can introduce something

that will enable them to stand up against that, the original strength does not matter so much in reason. Vanadium alone adds to the original strength as before stated; the elastic limit is increased say 25% and the ultimate tensile strength 10 to 15%, the same static ductility being kept. But when it comes to a question of alternating processes then we have an entirely "different story." Castings have often failed and chemical analysis has led one to believe they were all right, as did ordinary static tests. But testing on the alternating machine under the same conditions where good forged carbon steel stands 300 they would stand only 30 or 40 and then break. The ordinary casting will perhaps go 60 to 100, though it may give the same results from a tensile point of view and from a chemical point of view, as the forged carbon steel. Plain castings do not stand alternating tests nearly as well as where a casting is helped by vanadium, which metal also helps the founder because it "steadies" the metal and makes it flow nicely.

From what has been said, it is perfectly evident that we can use vanadium almost as we want. If we want static results we can get this by the suitable harnessing of vanadium with the other constituents; if we want dynamic results we can get them; if we want combinations of the two we can get them; if we want the preponderating influence to be static, but with some dynamic improvement, we can get it; if we want the preponderating influence to be dynamic with some static improvement, we can get it. Vanadium, then, is a "king" among alloys by reason of the fact that it can act in different directions.

Of course, there are as many types of vanadium steel as of a carbon steel. There is one type which is especially suitable for gun barrels, another type suitable for axle work, another type suitable for springs, another type suitable for case hardening, another type suitable for mild welding steel which will be put into very drastic service where high initial strength is not so much desired as the fact that that metal will always be the same and will not get "tired" and break up

in use. Each of these types within itself would give material for an evening's lecture.

Take crank shafts, for instance. There are some thousands af vanadium steel crank shafts in practical work and the figures I will give you are typical and not just snap instances. In a crank shaft we have to consider strength and rigidity; if a gasoline engine crank shaft is in question we must consider the effect dynamically of repeated impacts because that crank shaft is getting perhaps 2400 of these a minute, if it is of the four-throw type; while last but not least a good wearing surface on the bearings is a necessity. You cannot deduce those points with simply a static machine and a chemical analysis of four or five elements. Suitable vanadium steel will have an elastic limit of 115,000, and an ultimate strength of about 132,000 pounds per square inch, with an elongation of 21 or 22% and a reduction area of about 60%. Where ordinary good structural carbon steel will stand a shock of 10 foot pounds that will stand 12. (If you could get carbon steel up to an elastic limit of 115,000 pounds I would not like to say how many foot-pounds of shock it would stand, but probably something in the second place of decimals.) Where the carbon steel stands 900 alternating impacts before fracture, this class of vanadium steel will stand 1800. It has a close grained sorbitic structure which is especially suited to resist wear; under 350 magnifications the polished and etched surface appears almost homogeneous. In tempering carbon steel to attain this microstructure we must sacrifice other properties (its static ductility or its power of resisting alternating stresses) while at the same time we have lines of weakness running through the ferrite.

Another type of vanadium steel is the spring type. When it is tempered in the spring the elastic limit is over 220,000 lbs. per square inch and yet we have a reduction of area of 39%, showing that it is still a ductile steel. That spring will not only support more dead load without fear of breaking than will ordinary carbon spring steel, but it will live many times as long, as has been actually proved by practice.

Large numbers of vanadium springs have done and are doing great work in Europe.

When it comes to case hardening that is so complex a subject in itself that its discussion would fill up several evenings. We make use there of the toughening effect of vanadium on supersaturated carbon steel and at the same time its strengthening, toughening and vitalizing effect on the soft core of the material.

In the question of machining, alloy steels often give rise to difficulty. But that is not the case in machining vanadium steels. It may be said that vanadium steel will machine as easily as carbon steel of the same "temper."

In another type of steel we make use of the action of vanadium in automatically retarding the segregation of the carbides so as to obtain steel which is capable of resisting wear without tempering at all. Here in rails alone we have an enormous field. It is no easy matter to temper a rail, while an ordinarily tempered rail would not be equal all through, and most engineers will agree that unless the structure *throughout* is the same we are not going to get here the best results as regards resistance to wear, and that it is not sufficient to get a certain condition on the surface that is subject to wear only.

With further regard to the rail question, the trouble, I think, is not, as some newspapers say, all due to the effect of piping, nor to the effect of "rushing through over-crowded mills," nor is it due to initial brittleness; it is mainly due to the "potential brittleness" that we have been discussing so much this evening, and we must retard the development of this brittleness in order to arrive at the true solution of the problem. Other causes are certainly contributory and no sane man will maintain that a segregated rail is as good as an unsegregated rail or that it does not matter if the rail is piped. Eliminate the segregation, eliminate the piping, and we are two steps to the good, but we are not touching the real root of the difficulty. Vanadium is the certain cure here and the increased wear of vanadium steel should so make up for the

increased first cost as to lead us to gain in safety (or insurance) at little or no additional expense in the long run. An adequate discussion of this subject would occupy a very large amount of time.

The speaker has been very much blamed, unjustly, because of some remarks attributed to him on the rail question. For instance, he was credited with saying that we know that all Swedish rails will break! What he did say was that if rails could be made from Swedish iron they would be found to be very much better, and that rails that had been made of it had given exceptional results in service because of their property of resisting vibratory determination. These rails contain vanadium naturally.

Other applications of vanadium are many. Take the subject of armor plates. There we must have resistance to penetration, and the plate must be mild enough to withstand sudden impact without shattering, but stiff enough to allow the ball to pass through. The tensile test obviously cannot tell us all this and we cannot deduce very much by analogy because the analogy is not always the same. We must have recourse to the indentation test, to the shock test, and to other special tests.

Again we have the question of solid and rolled wheels where we have very much the same conditions to face as we have in the question of rails.

But I have already talked longer than I intended and I will say no more, but simply content myself with thanking you very much for the kind attention with which you have listened to me and ask you to pardon any incoherence.

DISCUSSION.

The Chairman: A number of our members have been very much interested in this kind of steel and perhaps some of them can tell us something about it. Mr. Smith, have you done anything with this?

C. C. Smith: About a month ago we were induced by the American Vanadium Co., of Pittsburgh, and by our own

desire, to make a trial heat of steel and pour it into locomotive frames. We did so and I have gone into the testing of this steel, as compared with our ordinary steel, very extensively, for us. I am sorry to stay we have not facilities for making dynamic tests ourselves. We have sent samples of the Vanadium steel and of our ordinary steel of similar analysis to some half dozen laboratories where they are prepared to make tests, but we have not had a report from a single one. Mr. Smith might account for one set of the samples here tonight. I was in hopes he would.

The Vanadium steel which we made analyzed in the ordinary determinations.

COMPARISON OF VANADIUM STEEL WITH ORDINARY STEEL.

AVERAGE OF THREE SAMPLES EACH.

	Ordinary Steel	Vanadium Steel
Elastic limit, per sq. in................	45,415 lbs.	56,285 lbs.
Tensile strength, per sq. in............	71,323 lbs.	82,183 lbs.
Elongation in two inches..............	29.8%	23.8%
Reduction of area	42.2%	37.03%

The samples which I have tested in comparison analyzed about the same. And in all cases I have selected good heats.

First I will say that we attached our test bars to our castings in that form (showing sample). That is cast under the casting. We get better tests under the drag of the mould than in the cold, as some of you know. We break that off by striking it with a sledge. This is a piece of our ordinary steel, very good stel. It broke off by hitting it ten blows with a 10-lb. hammer. This (showing another piece) is a piece of Vanadium steel made in the heat I mentioned and we used the same 10-lb. sledge and it took 137 blows to break it. The fracture is also very good. This is the best evidence I have to date of the superiority of Vanadium steel.

We took a 1 in. by ½ in. bar of Vanadium steel and a 1 in. by ½ in. bar of our ordinary steel and bent them flat upon themselves. The Vanadium steel bent flat without any crack whatever. Our ordinary steel bent flat on itself, but at the

last blow it sheared slightly. I might say before going further that the steel poured excellently, the working of the steel in the furnace, in the ladle and in the moulds was as good as any we have ever had and the results we got, so far as solidity is concerned, were better than our average.

This (showing another piece) was turned from a solid piece of Vanadium steel. There is not an imperfection in it. Of the five frames we made, not a single one had to be patched or repaired in any manner to be put into use.

This (showing samples) was a rather severe test. I took two pieces of steed 1 in. by ½ in. and bent them to an angle of about 90°. I then straightened them out and bent them the other way to about 90° and then back again, etc. That was a more severe test than I had intended. I only intended them to be straightened and bent back the same way. Our ordinary steel bent twice to 90° and the third time to about 75° when it broke. The Vanadium steel bent four times to 90° and broke at 90° on the fourth bend. It showed perhaps 30% better bend than our ordinary steel. This means really more than that would indicate, as I will explain later. We tested three sampies of our ordinary steel and averaged them. Then three samples of the Vanadium steel and averaged them with the following results:

You will notice by this that the tensile strength and elastic limit were both increased materially, and the reduction in elongation were reduced in the Vanadium steel from our average. This indicates these bending tests mean that Vanadium represents more even than my reports show. We can get practically the same elongation and reduction with 82,000 lb. carbon steel, but we cannot get as high an elastic limit in 82,000 tensile strength carbon steel, and it would not give anything like the bending results we got from 82,000 Vanadium steel.

As to forging, I cut this bar in two and welded it and then pulled it in a testing machine. You see a slight fin, indicating that it was not perfectly welded on that edge, but you will notice by the fracture that it was a perfect weld up

to that point. This bar pulled 72,460 lbs. to the square inch before it broke, so that the weld was not very bad. I had our own blacksmith do this welding and asked him to do it carefully. It may be that it is more difficult to weld than ordinary cast steel, because our blacksmith knows that business pretty well. However, it will weld. Here is an illustration.

As I told you, I have not had results from the technical laboratories to which I sent samples, and cannot give you a technical report on this heat of steel, but from my own observation and the observation of the practical men in our shop, I have no hesitancy in saying that the best heat of steel we have ever made was the one made of Vanadium.

The Chairman: There is one point that has not been taken up in the discussion at all and that is the cost of this steel. What is Vanadium steel worth in comparison with other alloy steels?

Mr. Kent Smith: I am very much obliged to my namesake for having so fully verified the remarks I made.

I said as far as castings were concerned we were not using any other alloy than Vanadium—we were only expecting Vanadium therefore to do static intensifying to the extent of 20 to 25% increase in elastic limit and about 15% in the ultimate strength, which are just about Mr. Smith's figures.

Mr. Smith gave me a little "dig" about dynamic tests. I am as disappointed as any one that I have not got these particular test figures. At the present moment I have not my own laboratories equipped, but they are now being built and I hope soon to be able to undertake some extensive investigations. The dynamic tests that I do now have to be done on extemporized machines, and I am put to great difficulty in getting them done within a reasonable time; while the progress of the investigation has not been accelerated by the fact of the endurance tests being suddenly brought to a standstill by labor difficulties. I expect a report on those samples almost any day.

In regard to welding, there is certainly no difficulty in welding Vanadium steel. I have done considerable work in welding Vanadium steel and the Vanadium tends rather to help the welding than otherwise. It must tend to do that because it is an easily oxidized element giving a fusible oxide. There is no difficulty in getting a weld of about 90% strength with Vanadium steel, which is certainly not always the case with carbon steel.

As regards cost, the cost of Vanadium alloy on Vanadium content is $5.00 per pound. That sounds a truly alarming figure, but we have to remember that Vanadium is a very powerful element and has to be used only in "homeopathic doses," the maximum quantity of Vanadium necessary to be used being about .20% or .25%. It may be said that this is a very small quantity and that it sounds rather absurd to make all these statements I have made on that small basis. A medical analogy I quote is the analogy of strychnine. This is a wonderfully beneficent drug if properly used. If something is wrong with a man's heart there is nothing that will do much more good than an infinitesimal fraction of a grain of strychnine. (It is not necessary for one to be a doctor to predict the result if we administer several grains of strychnine to the patient.) Coming down to an analogy on different lines and making the metaphor analogous in our own particular line tonight, we all know the enormous influence of .2% of phosphorus; we know what striking differences can be made with .2% of oxygen (by tapping a steel that is not properly finished in the furnace). We all know the extraordinary results physically that are attained by suitably adding less than .1% of aluminum, therefore, is it very difficult for us to accept logically the demonstrated fact that .2% of Vanadium is responsible for a very large amount of good? Surely one element may do as much good in one direction as another does harm in another direction. In studying steel we must study traces. In fact, the careful steel maker must be an "apostle of traces."

Coming back to the question of cost. Vanadium is $5.00

per pound content; if the alloy used contained 25%, the value of that alloy is about $1.25 per pound. From those figures it is self-evident, making all allowances, that there is no difficulty in producing Vanadium steel at a cost fairly comparable to that of ordinary high grade nickel steel.

F. N. Speller: I think it is pretty safe to assume that we do not get any Vanadium content in steel until all the oxygen has been satisfied. How far is Vanadium responsible for the rather remarkable dynamic properties we get in Vanadium steel, and how much of this is due to the more thorough deoxidization which we perhaps never got before?

Mr. Kent Smith: Mr. Speller has raised a very interesting point. Vanadium is, as has been stated, a very easily oxidized element. It will take oxygen from solid oxide of iron, which at once accounts for some of the earlier published figures being so contradictory, since those figures were always founded on the fact of so much Vanadium being *added*, and the assumption that therefore the steel contained that much Vanadium. If the steel was at all oxidized an equivalent amount of Vanadium disappeared in the slag. But there is no difficulty in producing a steel that is practically non-oxidized, and there is no doubt that Vanadium owes a certain amount of its beneficent action to the absolute removal of the last trace of oxygen. This trace need only be small as if Vanadium be carefully added to a thoroughly well worked down steel, the amount added and the amount which the steel is found to contain are fairly closely allied.

John M. Davidson (former member): Mr. Smith mentions gun barrels. I would like to know whether the use of Vanadium steel is shown by the reduction of erosion, or, due to the increased density of the steel, in minimizing or preventing the action of the acid fumes on the structure of the steel?

Mr. Kent Smith: From a number of practical trials made and still being made in noted arsenals, there is no doubt that the Vanadium barrels in resisting erosion are a great deal

better than ordinary carbon steel barrels. That I ascribe to the fact that these barrels are truly "Sorbitic" in structure. I do not say that the steel is any more dense, because if the carbon steel is well finished it has a density as good as you can obtain by the addition of any alloy. But "Vanadium" carbide is so well emulsified or "spread" through the steel that it seems to form a kind of protective coating and prevents the erosion that happens if you have a steel whose structure is more or less patchy. Under the microscope we can very easily differentiate metal constituents by the use of the weakest acids, such as an infusion of liqorice root in water. If you have the easily attacked ferrite protected by well disseminated carbide it must stand to reason that you have better resistance to erosion. (Let us distinguish between erosion and corrosion.) I believe the advantage is due mainly to these "mechanical" reasons, and in Vanadium steel we have a great advantage, as you cannot by any tempering of ordinary steel get the Sorbite "emulsified" so thoroughly and in non-weakened ferrite. If you get the emulsification by tempering ordinary steel you would not have a steel of the same resistance to the violent shock of explosion. That is why a suitably compounded Vanadium steel will for gun barrels be found better than any other steel at present made.

Alfred Sang: Judging from what I have heard tonight I should say that a small addition of Vanadium would be very beneficial to the mild open hearth steels used for making rivets and bolts. I have been thinking especially of automobiles. There is a good deal of shock and, therefore, danger of the head flying off, and we cannot tell if some accidents may not be due to this. Rivets on automobile frames are made of 3/8-inch material, which has to be drawn into wire and upset in a cold state.

Mr. Kent Smith: Vanadium will help that very much on account of improving the resistance to slight alternating shear impact. If we looked for the demonstrated improvement of such a class of steel to the tensile machine only, we

would say at once that the Vanadium had done no great amount of good, though it *had* really done a great deal of good. I am not only speaking from the scientific point of view, but from actual practice extending over a considerable number of years on the very question of rivets. The addition of Vanadium to ordinary pure dead mild steel practically produces something akin to Swedish steel and we all know that Swedish steel is very much better for rivets than is ordinary pure open-hearth steel. They may both show similar results on the tensile machine and in the ordinary "complete" analysis; but the Vanadium steel will stand work much better in service, and will make a rivet "live" very much longer. In England we used to make a specialty of Vanadium steel rivets for certain purposes, particularly in our hydraulic department. Before I ever published a figure on Vanadium steel I had a couple of years' experience practically in the shops with which I was connected. I published my first figures three or four years ago to the Institute of Mechanical Engineers in London and then I could allude not only to laboratory figures but to actual practical trials. And during the years that have intervened these practical trials have certainly not grown less. A practical comparative instance was brought to my notice three years ago. It was not a question of alternating shear but of pure alternating impact. I thus diagnosed the trouble of an engineer at once and begged him to accept a certain type of steel, but he said that this was no better than the steel he was using, judged by the tensile tests. He tried my recommendation, however, and has never used any other kind of steel since.

Mr. Speller: There is a question regarding the cost of Vanadium steel which has not been answered yet. What per cent of the Vanadium content added to the steel do we actually get in the steel in an average open-hearth heat and where all precautions are used to prevent the cinder taking up the Vanadium?

Mr. Kent Smith: It is perfectly feasible to finish an ordinary open-hearth heat so that it is practically free from

oxygen, and you will get about 90% of the Vanadium added to such steel. We have run through a good many balance sheets of steel made in this district, analyzing the slag as well as the steel. It is quite a simple matter to get 90% of the added Vanadium in the steel.

Mr. Speller: Did you have to use two ladles there?

Mr. Kent Smith: No, you can do it perfectly in the one ladle. Certainly, in my practice in Europe I used two ladles in order to thoroughly deoxidize the steel in the first ladle, as I found that the increased economy and regularity obtained more than paid for the extra trouble in the lining of the second ladle. One should deoxide the steel very thoroughly before adding the Vanadium and it is easily feasible to so deoxidize in the furnace. Of course, if we add the manganese in the furnace, especially the basic furnace, we have to look for a greater manganese loss. Where I use two ladles I do all the deoxidizing in the first ladle, then tap through a large nozzle into the second ladle. It is most practicable to do this where one is dealing with large sized casts, as you have no heat reserve to warrant using two ladles when you have only two or three tons. With a 15 or 20-ton cast it is practically easily possible to use two ladles, tapping very hot into the first ladle and seeing to it that the nozzle and stopper of the first ladle are big enough.

C. C. Smith: I would like to suggest that Mr. Speller is putting Mr. Smith into an awkward position. The heat we made we had analyzed by half a dozen chemists and no two of them got it alike. It (the Vanadium efficiency) ranged all the way from 90 to 120%. It does not appear to make very much difference how much you get out of it so you get the advantages Mr. Smith talked of. No two chemists will get it alike, and I don't suppose any one of them will get it right.

Mr. Kent Smith: There is no doubt that the analysis of Vanadium is difficult in the sense that it is "tricky." If you analyze your slag and your steel and obtain the proper propor-

tions of both, and the total quantity of Vanadium thus found is equal to the amount of Vanadium put in, it gives good proof that the analysis is correct.

Robert A. McDonald: I hate to hear Mr. Smith slander the chemists and I want to show him that he is mistaken when he says the American chemists cannot analyze Vanadium. I have been making quite a number of tests of various carbons, while those referred to seem to have been made on soft steel. The tests I have been working on have been more on the lines of tool steel. And the tests, as far as I have gone, practically uphold both the Mr. Smiths so far as the advantages of strength and adding considerable toughness to the steel. These small samples I have here are a higher carbon steel and it was more for the effect of heat treatment; that is, heating the steel up to about 2300° Fahr. and letting the heat run back gradually to a safe hardening heat, to see what effect the presence of Vanadium would have on carbon steel. It shows that practically the same carbon and other elements similar, with a little over 0.2% Vanadium, would harden clear through in one inch sections, while straight carbon steel would practically harden about $\frac{3}{16}$ in. deep.

The presence of Vanadium seems also to have an effect on the hardened fracture; for the heat treatment does not show as effectively as on a straight carbon steel, and may have some influence in protecting steel when it is slightly overheated. That is a point Mr. C. C. Smith brought out well in welding in soft steel. I tried it on high carbon steel and I found it was a little difficult to weld to iron. In the first attempt to weld it, my blacksmith, not knowing its composition, handled it the same as a carbon steel and the first blow of the hammer it slipped from between the iron and flew all over the shop. The second time he made a perfect weld. In some of the tests I was making more for my own information than anything else, I made one of steel containing .38% carbon, without manganese.

I also made tests on annealed samples. In annealing Vanadium steel it reduces the tensile considerably, same as in

	Material	Elastic Limit Load Pounds	Elastic Limit Pounds Per Sq. Inch	Maximum Load Pounds	Tensile Str'gth Pounds Per Sq. Inch	Elongation Per Cent	Reduction of Area Per Cent
No. 1	No. 1—Natural Bar	10,200	52,800	14,900	77,120	30.5	57.
	No. A1— " "	11,200	57,970	16,500	85,400	21.	37.9
	No. 1—Annealed Bar	9,000	46,580	12,000	62,110	29.	54.3
	No. A1— " "	11,000	56,470	14,000	71,880	27.	58.7
No. 2	No. 2—Natural Bar	8,600	44,150	15,100	77,520	31.	56.
	No. A2— " "	17,400	89,320	22,900	117,500	18.	41.7
	No. 2—Annealed Bar	8,600	44,330	13,300	68,560	30.5	57.2
	No. A2— " "	13,600	69,820	17 100	87,690	26.	56.
No. 3	No. 3—Natural Bar	9,000	46,200	16,100	82,650	25.	44.8
	No. A3— " "	19,500	100,100	27,300	140,100	16.	37.1
	No. 3—Annealed Bar	9,100	46,920	15,000	77,330	30.	48.9
	No. A3— " "	14,000	72,460	17,400	90 060	23.	47.3
No. 4	No. 4—Natural Bar	11,000	56,240	17,200	87,940	26.	45.
	No. A4— " "	16,000	81,520	28,400	144,700	17.	32.7
	No. 4—Annealed Bar	10,900	55,730	15,800	80,780	28.	46.5
	No. A4— " "	14,000	71,330	18,800	95,790	24.	48.1
No. 5	No. 5—Natural Bar	19,500	99,340	23,500	119,700	15.	18.9
	No. A5— " "	22,300	114,000	31,300	160,000	10.	10.1
	No. 5—Annealed Bar	15,800	80,780	20,200	103,300	19.	25.7
	No. A5— " "	12,200	62,380	21,800	111,500	21.	42.

NOTE—All 2 in. Tests, ½ in. Turned Test Sample.

carbon steel. Annealed steel is always somewhat weaker than it is in the natural condition, either in treated or untreated steel. That was a .23% Vanadium. We figured on that for about .28% Vanadium, and taking the weight of the ingot produced we got nearly all the Vanadium we put in.

In another test of .26% carbon. See 2.
In another test of .50% carbon. See 3.
In another steel of .54% carbon. See 4.
In .78% carbon steel. See 5.

There is a peculiarity in the Vanadium steel. Take this steel of .38% carbon. You could shear the natural steel without any trouble. To attempt to shear the Vanadium steel it would fly. You could not get a clean shear at all, showing it is a much harder steel. The point of the set would fly off. And you could hardly break the bar. I had seven samples originally in this test. I could not break the other two samples of Vanadium steel with a sledge; I am going to break it with a steam hammer; while I could break the six pieces of carbon steel without any trouble. There is no question that Vanadium adds additional strength and hardness and shows up distinctly in what we call physical tests. And the fracture of the steel speaks for itself. The treatment being identical, the difference in the fracture here shows right on its face that the Vanadium adds virtue to it which it never had before. I take a few exceptions to Mr. Smith's statements, especially in the Swedish proposition. We do not find that Swedish iron contains any Vanadium that you can detect by analysis. We have analyzed many samples of it and we figure we have as good chemists as are in the United States or anywhere else, but we cannot get a trace of Vanadium in even the best grades of Swedish wrought iron.

Mr. Kent Smith: Do you mean Swedish puddled iron? This would not be expected to show much more than .02%.

Mr. C. C. Smith: Have you tried the bending tests on it?

Mr. McDonald: No, mine were made for strength and hardness.

Mr. Kent Smith: Vanadium itself is a hardening element and I am very pleased to find that your results absolutely agree with the statements I made about the intensifying action; as the other elements increase in amount the corresponding difference due to the action of Vanadium is greater. It has been fully recorded that there is an enormous rearrangement between the static and the dynamic attributes given by Vanadium at the recalescence point. In fact, speaking *broadiy,* if you want the dynamics in excess, you must treat above the recalescence point, and if you want the statics in excess you must treat below the recalescence point.

As regards the question of Vanadium in Swedish steel, we used a considerable quantity of Swedish steel at one works with which I was connected and I do not think I ever found a Swedish iron or steel that was absolutely free from Vanadium. In puddled iron where the iron has to drop out of solution, you do not expect to find as much Vanadium as in a melted steel. We used a good many thousand tons a year of mild Swedish steel and the average Vanadium in it was .05%. I do not make this statement as the result of one or two analyses but as the result of several hundred analyses. As regards the question of finding it in the brands I was working on and Mr. McDonald not finding it in the brands he was working on, much doubtless is due to the difference of the material rather than to the personal equation.

H. H. Anderson: The lecturer stated that there had been forged and rolled car wheels made of Vanadium steel. Was the mileage increased or the tendency to shell bettered by the addition of Vanadium?

Mr. J. Kent Smith: I am afraid you rather misunderstood me. I did not say forged car wheels had been made, but that in the type of steel particularly fitted for car wheels we met much the same proposition as in rails. As regards the actual use of steel for that purpose I was reasoning largely by analogy and by small trial tests, so that I am not able to answer the question as to mileage figures. A considerable number

of wear tests were made in connection with Vanadium steel of a good homogeneous emulsified sorbitic structure, such as is naturally opposed to shelling, and on account of these tests and comparative work we know that the car wheel question is one in which Vanadium deserves particular investigation. There are no figures on mileage that I know of as yet.

A. Stucki: I would like to know whether or not the steel casting samples mentioned by Mr. Smith were annealed or not, and if they were, I would like to know if the heat treatment adopted was the same as with ordinary steel castings? The latter, we know, have to be annealed just right in order to get the benefit of the excellent qualities laying dormant in this material, and it would be interesting to know whether Vanadium affects this process of annealing in any way.

Mr. C. C. Smith: I would say that the two steels were annealed as nearly to the same temperature as we could get them by the use of a Le Chatelier pyrometer. We carried our annealing furnace to 780°, the point at which we use a pyrometer, and they were both annealed to the same point. There is a change of structure in annealing, but not as great as in ordinary steel. But after it is annealed I find the same structure that this other gentleman did. My two samples are not quite as distinctly different as his are, but you can all see from where you are. The Vanadium steel in its raw condition is much closer grained than the ordinary steel. It shows a much closer, tougher fracture. Annealing, of course, reduces the granular effect and changes it in the same way as the ordinary steel, but not to such a great extent.

A Member: Does the Vanadium in the scrap in remelting oxidize to any great extent, and do you recover part or all of the Vanadium when it is recharged, as you do nickel?

Mr. J. Kent Smith: No. Vanadium is an easily oxidized element and the combination produces an acid radicle. If we charge Vanadian scrap into a basic furnace we will carefully refine out every trace of Vanadium in the scrap. In the acid

furnace the probability is that we will refine out 60 or 70%. In a crucible we will refine out about 50%. No claim for any especial virtue is made for the use of Vanadium scrap in ordinary practice. When I spoke about the manufacturing cost of Vanadium steel and nickel steel, I considered in that the fact that in the Vanadium steel cost the drawback for crop ends, etc., would be taken at ordinary scrap price, though the nickel steel scrap was taken at its advanced value.

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Chairman Sumner B. Ely

In the Chair.

Coke Drawing Machines

And Other Machinery for Use at the Ovens in the Manufacture of Coke.

BY WALTER W. MACFARREN,*

Non-Member.

THE COKE INDUSTRY.

"In the United States the manufacture of coke has hitherto been confined mainly to localities affording the best qualities of coking coals. It required little skill to make excellent coke from such good coals, but with the large expansion of the coke industry and the gradual exhaustion of the areas of the prime coking coals, compelling the use of the secondary qualities of coking coals," improved forms of ovens, and various mechanical devices for supplanting hand labor have become necessary and desirable, owing to the increasing difficulties of manufacture from the inferior coals[1].

"The manufacture of coke in the United States began in a feeble way, with four small establishments, in the year

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[1] Coke, by Jno. Fulton, partly from Preface.

1850." In 1892 there were 261 coke plants, with a total of 40,000 ovens, and the total value of the product was $23,500,000, at the ovens. In 1902 there was produced 25,400,000 tons of coke, of an average value at the ovens of $2.49 per ton, or a total value for the year of over $63,000,000. To produce this coke there was required about 40,000,000 tons of coal, or an acreage of coal land of about 4000 acres. On April 1st, 1907, according to tables published by the "Connellsville Courier," there were in the Connellsville and lower Connellsville regions a total of 37,000 ovens, in round numbers, with over 2000 additional ovens projected or building.

Assuming that only 35,000 of these ovens are in constant operation, their combined daily output would be over 70,000 tons of coke, requiring over 100,000 tons of coal, or about ten acres per day, for the Connellsville region alone. Of this total output only about 3000 ovens are machine drawn at this writing. It will thus be seen that the field for a good coke drawing machine is large.

FORMS OF OVENS.

The many forms of coke ovens can be broadly classified under two heads, the rectangular oven and the bee hive.

Ovens of the rectangular forms are almost exclusively used for making *by-product coke*. Also lately, the long ovens, having a width of from 4½ to 8 feet and a length of 30 to 33 feet, are again coming into vogue, on account of the lessened labor cost, due to the easy application of machinery to replace hand labor. These machines will be more fully described hereafter. Of all the ovens making "Connellsville coke," less than a hundred are of this form, at this writing.

The great majority of all coke ovens are of the bee-hive type. The standard bee-hive oven is 12 to 13 feet diameter, about 7½ to 8 feet high in the center, has an opening at the top called the "trunnel head," for introducing the coal, and a door at the side, for the extraction of the coke.

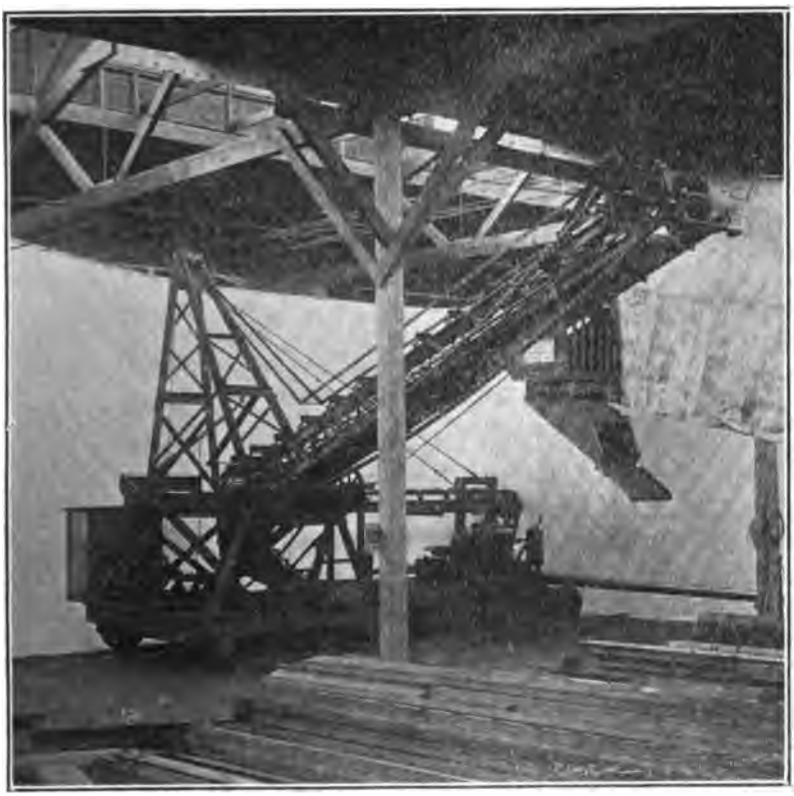
For hand-drawing the doors are usually about 2 ft. 6 in. wide and 3 ft. 3 in. high.

For machine ovens the doors are about 44 in. wide by 3 ft. to 3 ft. 6 in. high.

The bottom of the ovens is floored with tile, 12 in. square by 4 in. thick.

PROCESS OF COKE MANUFACTURE.

The coal is charged in the trunnel head from a "Larry" above the ovens. It is then leveled by hand, with a scraper. The door is then bricked up and luted with clay, leaving the proper air space for entrance of air above. The coking process then starts from the heat contained in the oven walls and con-



No. 1. The Marmac Machine.

tinues from 40 to 70 hours. The amount of coal charged depends upon the length of time it is to coke. When the coking process is complete, usually 44 to 46 hours after charging, the door is removed and the oven quenched or watered by hand with a hose. The oven is then drawn and recharged as soon thereafter as operating conditions permit.

STRUCTURE AND PHYSICAL PROPERTIES OF THE COKE.

After the coking process is completed, the coke stands in the oven divided by substantially vertical strata or seams. A thin layer of ash covers the top. The best coke is extremely hard and brittle. The dust of the coke is comparable only to emery in its destructive action on machinery. The coke, as it stands in the oven, is in a solid mass, with the exception of the vertical strata referred to, and these are close-fitting and locked together.

To illustrate this, the writer has seen a charge of coke pushed from a rectangular oven 5 feet wide and 30 feet long, onto a flat platform made of oak planks, on the level of the oven bottoms, with only a hatful of coke sprawling off the sides. This coke had to be separated with a pick to enable it to be forked into cars.

DRAWING COKE BY HAND.

From the above, it will be seen that the process of drawing coke by hand involves the hardest kind of manual labor. In addition to the resistance offered by the coke itself, the snow, cold and slush of winter, and the heat of the sun in summer, in combination with the heat from the ovens, together with the dust and fumes in all seasons—combine to render the work of extreme difficulty. Few Americans would work at it, and with the continued expansion of the coke industry, the class of labor which will stay at it, becomes increasingly difficult to obtain.

Mr. W. H. Clingerman, general superintendent of the H. C. Frick Coke Co., said lately to the writer on this point: "The coke drawing machine has come to stay. It is not only

the direct saving in cost of production shown by the machine plants, but the labor to draw by hand can no longer be obtained."

SAVING IN TIME BY COKE DRAWING MACHINE.

The average time required to draw an oven by hand is about three hours. The average by existing machines is well within 15 minutes. There is thus a saving of 2¾ hours, which, if utilized, can be made to produce about 5% more coke. Much of the possible saving in time is lost, however, in present practice, by antiquated methods of watering and delay in recharging the ovens. The time lost between watering the coke in the oven and the introduction of fresh coal for coking, is a loss in two ways: First, it is a direct loss per se. Second, with the door open and the coke watered, every minute the oven stands it loses heat by radiation, so that the coking process starts so much slower after the new coal is introduced.

SAVING IN COST OF DRAWING BY MACHINE.

The coke drawing machine saves money directly over hand drawing. The scale price for hand drawing is $1.12 per oven. The machine will do this for less than half.

At the Frick Coke Co.'s Continental No. 1 plant private tests were made, covering a year's operation, which showed the cost of hand drawing to be $1.14, and of machine drawing (including repairs to machines and ovens, and a sinking fund to cover cost of machine), to be 52c per oven, or a saving of 62c per oven. (These figures are believed to be reliable, but they cannot be officially confirmed.)

At the rate of 50 ovens per day per machine, this saving would amount to $30.00. The saving on the 18,000 ovens drawn per day in the region, at 50c per oven, would be $9,000 per day, or nearly $3,000,000 annually.

SIZE OF COKE DRAWN.

By hand drawing the coke is drawn from the oven in nearly its original size as coked, and a considerable portion

of it reaches the railroad car in this state. All coke drawing machines break up the coke more or less in the extraction, and still more in conveying it to the car. This has been one of the principal objections to the introduction of the machines. However, when it is considered that the coke drops from 4 to 10 feet into a car, is transported several hundred miles to destination, and then often passes through coke bins requiring further drop, it is seen that, in many cases, it is of necessity small when used.

Mr. R. M. Waite, late assistant to the president of the Colorado Fuel & Iron Co., told the writer that the total drop or fall of their coke, in several successive handlings from ovens to furnace, was in the neighborhood of 70 feet.

A great deal of the opposition to machine coke has been the result of prejudice and some furnace men admit the superiority of a smaller uniform product over a mixed product of large and small pieces.

The very fine coke or breeze is usually a dead loss, although in some cases it can be sold for domestic use.

The following data on breeze coke is supplied by Mr. R. L. Martine, Jr., Assistant Manager of the Bessemer Coke Co., as illustrating their practice at the Griffin plant:

Breeze coke from hand drawn ovens..... 600 lbs.
Breeze coke from Marmac machine..... 950 lbs.
Breeze coke from Covington machine...1300 lbs.

The problem to be met in the design of a coke drawing machine is thus seen to be of no small size and in support of this assertion, it is on record that there have been many failures in this line.

The essentials of a good coke drawing machine may be stated as follows:

First—Reliability. After the machine is installed and the labor gone, the output of the plant depends on the machines.

Second—Capacity. A machine which will draw 50 ovens to another machine's 40 in the same time, is, of course, the better.

Third—Economy of operation. This would include the items of power, operating labor, maintenance, interest on first cost, etc.

Fourth—The delivery of large, clean coke to the cars.

Fifth—A low construction of machine or a "high" yard, permitting the drawing of the coke by hand when occasion required.

Sixth—As nearly "fool proof" as possible.

Seventh—Low first cost of machine and installation.

The writer believes the relative importance of these factors to be about in the order stated—in other words, the first cost of the machine is the last thing to be considered.

PATENTS COVERING COKE DRAWING MACHINES.

Many mechanical devices were invented and used for charging and discharging gas retorts upwards of 30 years ago.

The following patents relate to removing the coke from bee-hive ovens:

G. W. Bierer, No. 314,510, March 24, 1885.

Bierer shows a rack driven scraper, working over the coke and dragging the same on to a conveyor at right angles to the oven, to load it on cars or carts, the whole driven by steam.

The apparatus shown is very crude, but it will be noted that it contains a conveyor, which is an essential part of the present machines. The machine moves on a track in front of the ovens.

F. C. Weir, No. 362,130, May 3, 1887.

The same general description as for Bierer, will apply to this patent, with the conveyor omitted.

N. O. Goldsmith, No. 435,891, September 2, 1890.

The Goldsmith machine is one of the most carefully worked out of all the older patents and was evidently the work of an engineer. It is a steam machine, having a 3-cylinder reversing engine, operating a rack driven

ram, carrying a scraper, which attacks the coke from above.

The machine is provided with fluid pressure cylinders for elevating and depressing the ram to force the scraper into the coke, with a turntable for swinging the ram, and with a worm drive to the track wheels, which is a detail of construction used in the Marmac machine, to be described later.

This machine has no conveyor, being an extratcor simply.

Thos. Smith, No. 446,936, February 24, 1891.

Mr. Smith's patent marks the greatest advance of any single invention relating to coke drawing machines. and is the basic patent on the wedge or "underworking" shovel.

Without this invention the present successful machines, viz.: the Covington and the Marmac, would have been impossible.

Mr. Smith's patent is dated February 24, 1891, and would be still alive were it not for the fact that it was previously patented in England in 1888 and expired in this country 14 years later, in 1902, on the expiration of the English patent.

He shows an extractor only. This consists of a truck carrying a steam engine coupled to a rack driven ram, on the outer end of which is mounted a curved wedge, having a square back.

This wedge was forced under the coke, sliding on the oven bottom, and loosened the coke on its in-stroke, the same falling over the high part of the wedge at the rear, and being withdrawn on the out-stroke.

The rack teeth were on the side of the ram bar and the driving pinion was mounted on a vertical shaft.

The ram bar was guided by rollers, supported by a framework, pivoted about the vertical driving shaft, so that the shovel could explore all parts of the oven.

The present Covington machine employs an almost identical construction, with the addition of a conveyor.

The Smith extractor is illustrated in Mr. John Fulton's Treatise on Coke (Scranton, 1905,), as in operation at the Latrobe Coal & Coke Co.'s plant.

J. A. Montgomery, No. 563,781, July 14, 1896.

This patent shows a conveyor which enters the oven back of a wedge which lifts the coke on to the same, after the coke has been slit into slabs by a circular saw, mounted on the front of the apparatus. It does not look very practical.

A. M. Bacon, No. 669,377, March 5, 1901.

Mr. Bacon hails from this city. He shows a scraper actuated by a fluid pressure cylinder, and is, I believe, the first to suggest this.

No conveyor is shown.

B. J. Matteson, No. 722,599, March 10, 1903.

This patent discloses an overworking scraper, delivering the coke to a conveyor at right angles to the ovens.

We now come to the patents of **Mr. Jno. A. Hebb,** who built a machine in 1902, which was tried at the Frick Coke Co.'s Continental No. 1 plant, near Uniontown, and which will be described later.

These patents are numbered as follows:

No. 727,790...........	May 12, 1903.
No. 727,942...........	May 12, 1903.
No. 727,943...........	May 12, 1903.
No. 728,102...........	May 12, 1903.
No. 728,102...........	May 12, 1903.
No. 728,168...........	May 12, 1903.
No. 749,058...........	Jan. 5, 1904.

Mr. Hebb's machine attacked the coke from the top and his extracting mechanism was substantially anticipated by earlier inventors.

He is, however, the first to show a pair of conveyors, one alongside the ovens for receiving the coke from the extractor, and the second inclined conveyor at right angles to the first one for elevating the coke, and delivering it to a car.

This latter conveyor was made of slats with spaces between, which screened the ashes and fine coke out, en route to the car.

This arrangement of conveyors, with details almost identical with Hebb's patent drawings, is used on the Covington machine at the present time, and in fact was the necessary addition to the Smith extractor, to render the Covington machine of commercial use.

J. E. Jones, No. 731,912, June 23, 1903.

The Jones machine is an extractor only. It is shown in connection with a small car similar to a mine car between the machine and ovens, into which the coke is drawn directly.

The extractor is generally along the lines of Smith's, except that two ram bars are used, one having a wedge going under the coke and the other mounted vertically above the first, having a curved frame similar in shape to an inverted basket to come down over the coke for withdrawal.

A second patent to the same inventor, No. 731,913, of the same date, shows a similar machine, with only one ram, having a wedge shaped shovel made in two parts, so that the upper side of the same, after being projected into the oven under the coke, could be raised to an angle of about 45 degrees by means under control of the operator, and thus carry the coke out of the oven. Mr. Jones has done considerable work along this line, but has not yet produced a machine of commercial value.

W. H. McConnell, No. 768,067, August 23, 1904.

(Assigned to the Covington Machine Co.)

This patent shows practically a copy of the Smith extractor, with a two-cylinder engine having a vertical crank shaft to drive the ram.

F. D. Buffum, No. 786,623, April 4, 1905.

This patent shows a complicated mechanism comprising a box-shaped shovel, to be inserted in the coke and dumped by rotation on withdrawal.

There is in combination a skip hoist to receive the coke and deliver it to a railroad car.

J. S. Ham, No. 803,586, November 7, 1905.

This patent shows an ingenious construction, consisting of a hinged ram bar with the Smith shovel. The hinged bar folds up automatically on withdrawal, thus decreasing the space required for clearance at the rear of machine.

It is adapted to be used on a narrow yard. So far as known, the construction has not yet been used in practice.

Mr. Ham is president of the Covington Machine Co.

H. F. Pearson, No. 804,670, November 14, 1905.

This patent shows an extractor only. It consists of a truck on which is mounted a turntable. On this turntable there is a box-shaped ram, containing a conveyor.

The front of the box is provided with a wedge to go under and loosen the coke. Over this wedge there is a set of star-shaped wheels, to pull the coke onto the conveyor.

The conveyor box has an opening in the rear end and the coke is dropped onto the ground at the rear of the machine.

I. C. Kelly, No. 807,118, December 12, 1905.

Mr. Kelly shows a pneumatic extractor, comprising two cylinders mounted on a truck. One of said cylinders operates a pair of tongs opened and closed by compressed air, to remove the greater mass of coke. The sec-

ond cylinder operates a scraper to remove the fine coke remaining after the tongs have removed the major portion.

No conveyor is shown.

D. A. Ramage, No. 812,364, February 13, 1906.

This patent also discloses a compressed air or steam extractor with a peculiar broad shovel, to be forced under the coke.

The coke is carried out on the shovel and dumped into a small car between the machine and oven.

C. P. Ludwig, No. 832,988, October 9, 1906.

Mr. Ludwig shows an over working scraper for pulling out the coke, very similar to the Hebb machine.

The coke falls into a bucket or basket, which can be handled by a crane.

He also uses the apparatus for leveling the coal.

R. L. Martin, Jr., and W. W. Macfarren.

Not yet issued. Separate patents on extractor and conveyor. These patents fully cover the Marmac machine.

EXISTING MACHINES.

The coke drawing machines existing at the present time, as far as known by the writer, may be divided into two classes, with relation to their method of attacking the coke, viz.: The over drawing machines and the under drawing machines.

To the first class belong the Hebb machine, of which there is at present one under course of construction for Jones & Laughlin, and the machine at Continental No. 1 plant, H. C. Frick Coke Co., designed by Mr. Fred Danniels, Chief Engineer of the American Steel & Wire Co., and built by the Alliance Machine Co. To the second class belong the Covington, the Heyl & Patterson and the Marmac. These three latter machines use the Smith under working shovel in its original form.

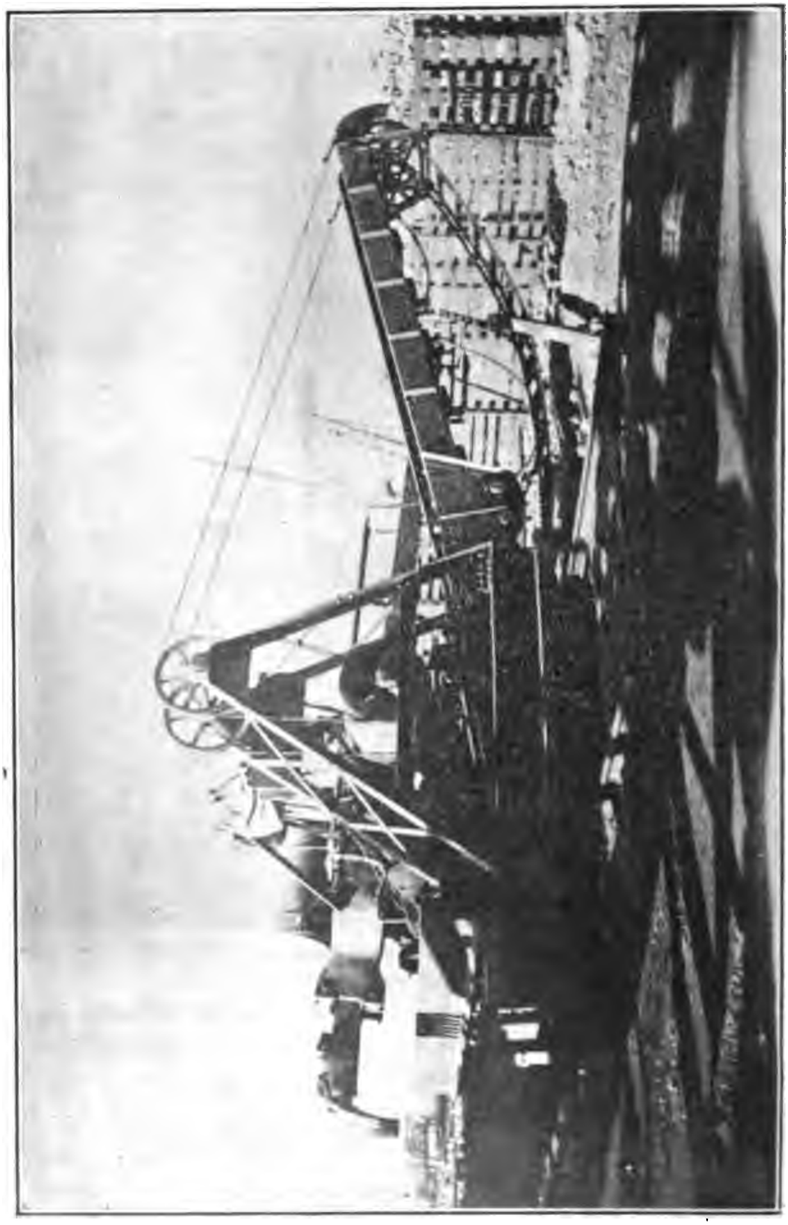
THE HEBB MACHINE.

The Hebb machine was described in "Mines and Minerals," February, 1904. None of these machines are at present in use, but one is under construction for Jones & Laughlin.

No. 2. Hebb Machine as tried at Continental No. 1.

The following quotation is from a letter to the writer from Mr. E. H. Abraham, formerly superintendent at Continental No. 1 plant, of the H. C. Frick Coke Co.:

"The Hebb coke drawing machine was tested out at this plant in 1902, and was a failure." The writer has seen Jones & Laughlin's Hebb machine unassembled, and does not expect it to be successful.



No. 3. Alliance Machine at Continental No. 1. Note resemblance to Hebb Machine.

THE ALLIANCE MACHINE.

This machine is an instance of first-class workmanship and poor design. It is broadly a copy of the Hebb machine, with variations in details. It has three electric motors, three air cylinders and an air compressor. The ram bar enters over the coke and has a set of hinged fingers which enter the oven horizontally and are pulled down on the coke by an air cylinder at the rear end of ram. The ram has a vertical tilting adjustment, power operated, by means of two air cylinders. The ram and its operating mechanism are carried on a turntable, rotated by a motor.

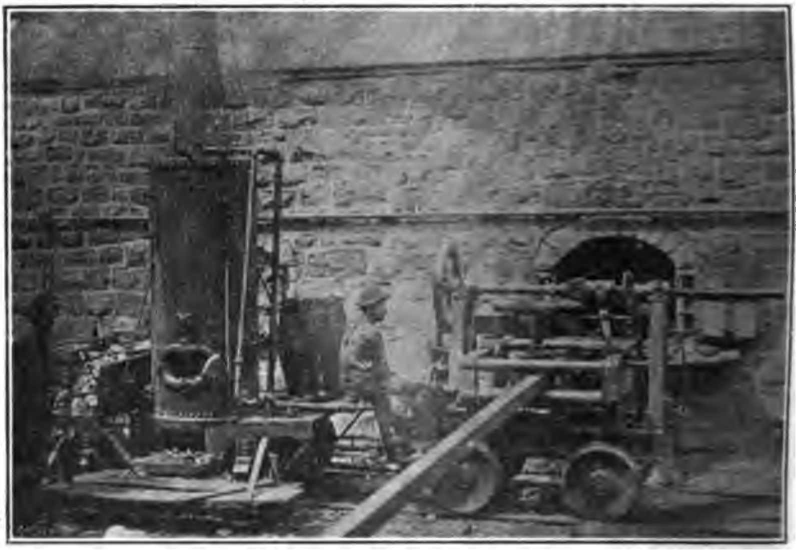
The machine was evidently constructed without regard to expense, cut gears being used almost exclusively and plenty of them. There are never less than eight gears between a motor and its work. The motors and controllers are of the open type, without any protection from the weather. The machine has been at Continental No. 1 since June, 1907, and has drawn about three ovens. The machine appears to be designed more for exhibition than for service and the use of finely finished mechanism and electrical apparatus, without protection of any kind from weather or coke dust, shows a lack of familiarity on the part of its designer with operating conditions at a coke plant. The conveyor is a copy of the Hebb design, but is rather inadequate for the service, being too light and flimsy.

THE COVINGTON MACHINE.

The Covington coke drawing and loading machine was the first "complete" coke drawing machine to attain any degree of success. There are at present more of them in use than all others combined. The original Smith machine was an extractor only—the Hebb machine had a good conveyor, but failed on account of its extractor. The Covington machine combines the Smith extractor and the Apron conveyor, both almost identically as conceived by their separate inventors.

It can thus lay no claims to originality, but it was the first coke drawing machine to do the work—that is, to remove coke

from an oven and place it in a railroad car without manual handling. The success achieved in this respect and the overcoming of the initial prejudice to a great degree against machine drawn coke, has invited competition by improvement, as in the Marmac machine, and by practically duplication, as in Heyl & Patterson's machine.



No. 4. The first Covington Machine, steam-driven. Installed at Low Moor Iron Co. in 1901.

As shown in the accompanying illustrations, the machine consists of an extractor and a conveyor. The extractor is operated by a 20 H. P. motor, there being six gears between the motor and ram. The ram carriage is pivoted about the centre line of the vertical driving shaft, to allow of pointing it in the direction desired. This swinging is obtained by a hand wheel and screw, and the necessary elbow grease.

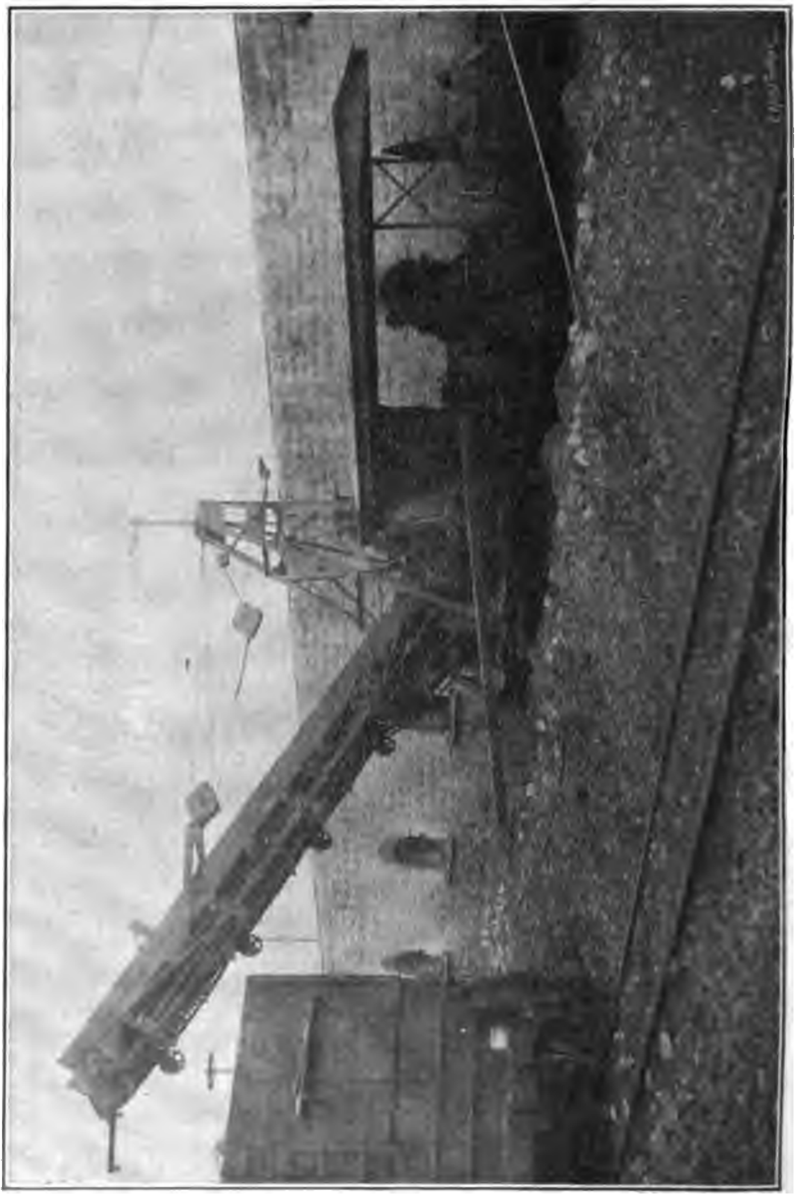
This feature of the machine makes it necessary that there be two men to run it, as one operator cannot stand the combined heat, dust, and labor of swinging the ram continuously. The form of ram drive (from below) and conveyor make

necessary a distance of 3 ft. 5 in. from oven seat (floor of oven) to the top of rail. This renders it extremely difficult to draw the ovens by hand, the desired height of yard for this purpose being 2 ft. 6 in. below oven seat. It also entails additional expense in installation, as in old plants about 15 to 18 in. has to be graded out for the machine track. In new plants the same amount of masonry has to be built.

No. 5. First Covington Machine.

The grading of a coke yard, packed with fine coke for years, is not easy. In one case, within the writer's knowledge, the cost of grading the yard for a Covington machine was over $2,000, or nearly half the cost of the machine. This did not include the cost of track.

The Covington machine is cheaply constructed. Except for a small amount of structural steel, the greater part of the machine is built of cast iron. In the writer's opinion, there



No. 6. The late Covington Machine at Wynn.

should be no cast iron used in the extractor. The jar when the ram strikes the rear of ovens is sufficient to lift the front track wheels off the rail, and the writer has seen the track shoved bodily over 1 in. back by this occurrence on the Marmac machine (due to mal-adjustment of clutch).

The ram driving gears on the Covington machine are, of necessity, steel, and it is a wonder they stand the service at that. Nothing in the writer's experience, including several years in rolling mills, shows anything to equal the terrific back lash in these gears. The ram is driven by a reversing motor, having a drum type controller, with notches on both sides of the central "off-point."

The controller handle never stays at other than the central or the extreme points and only at the former when the machine is stopped. The operator swings the controller handle gracefully from the "loop" in one direction to the "loop" in the other. There are three sets of gears in the train, the spur armature pinion and its gear, a bevel pinion and its gear, and the rack pinion and rack.

In full operation the motor is reversed, as above described, upwards of twenty times a minute, and it is not necessary for the plant superintendent to have a telephone at night to determine whether the machine is operating, if he lives within a mile.

The conveyor consists of two parts at right angles. The first part extends under the oven door and receives the coke as it is withdrawn by the extractor. This conveyor is level under the oven door, and then rises about 18 in. to the point of discharge, where the coke falls onto the loading conveyor. Both these conveyors are of the "apron" type and carry the coke on their upper strand. The receiving conveyor has flights close together and carries coke and ashes, but the loading conveyor has flights about 2 in. wide, with 3/8 to 5/8 in. space between, to screen out the ashes and fine coke. The loading conveyor is carried by small Idler sprockets, about 4 ft. apart, and the screening action is very perfect owing to the vibration and curving of the conveyor. In fact, the conveyor some-

No. 7. Late Covington Machine at Wynn. Note moving platform necessary for leveling.

times loses small coke between the flights and the stationary side guards, and makes more breeze coke than is desirable. The loading conveyor is adjustable vertically to suit different heights of cars. It has no adjustment laterally. Coke can be delivered only off the end of the conveyor. Both conveyors are driven by a 10 H. P. enclosed motor. The drive for track wheels is from the extractor motor by means of a crab clutch. Although the extractor brings out the coke intermittently, a bushel or two at a time, the loading conveyor delivers the coke to the car in a practically constant stream.

No. 8. Covington Machine at Griffin.

Owing to the fact that the vertical pivot around which the ram swings is located about 7 feet from the oven door, it is necessary to make three settings of the machine to reach all the coke in the oven; first centrally in front of the door; second, about 2 feet to the right to reach the coke on the left, and

lastly, about 2 feet to the left, to reach the coke on the right. This involves some loss of time.

A feature of the machine is the collection of weights, or "pendulum" suspended at the rear to preserve equilibrium. This is somewhat terrifying at first sight, when the machine is suddenly moved. According to Mr. Enoch H. Abrahams,

No. 9. Covington Machine at Griffin.

the Covington machine has made records as follows: 40 ovens in 5 hours, 112 ovens in 16 hours, 40,000 ovens for 3 machines in one year.

The average speed of the machine, under favorable conditions, is about four ovens per hour. At the Griffin plant of the Bessemer Coke Co. they are regularly drawing 50 ovens per day in from 12 to 13 hours.

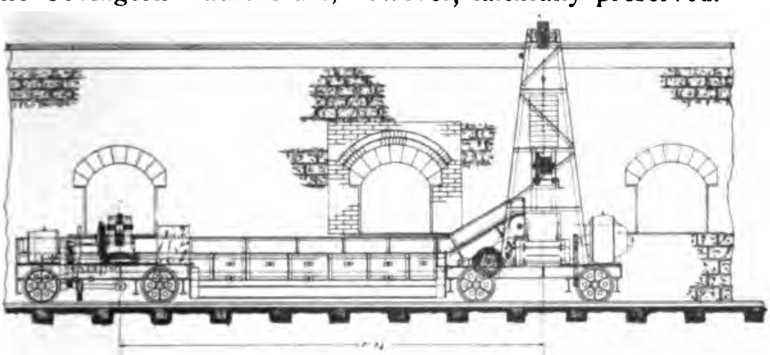
Mr. Fred C. Keighley, General Superintendent Oliver & Snyder Steel Co., writes me as follows: "We have two Covington machines at the Oliver No. 1 plant; their average work is 40 ovens per day per machine. They can do this work in ten hours when there are no interruptions. We have two of these machines at our Oliver No. 3 plant. The ovens there are 13 ft. diameter, while the ovens at No. 1 are only 12 ft. diameter. We find that the machines at No. 3 can draw 40 ovens a day, but it takes probably an hour a day longer on acount of the greater capacity of the ovens."

The machine draws upwards of 90% of the coke in the oven, the remainder lying scattered on the oven floor. This is removed by hand. In order to draw it directly into the conveyor, the receiving conveyor on the later machines has been extended to take in two oven doors.

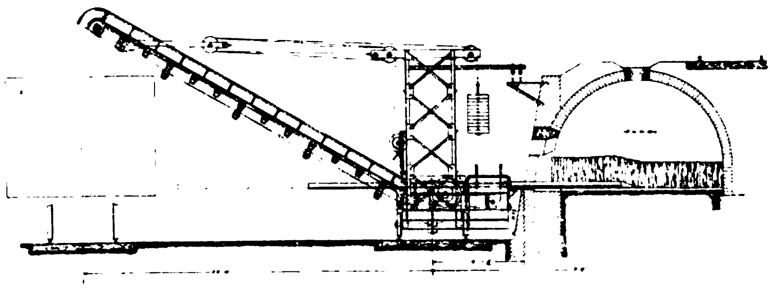
In spite of its many mechanical crudities, the Covington machine was the first to achieve commercial success, and owing to its having no competition until about six months ago, they have the greatest number of machines in use.

THE HEYL & PATTERSON MACHINE.

The Pittsburgh firm of Heyl & Patterson are planning competition on direct lines. This machine is practically a copy of the Covington, with the exception of details, which are better worked out. All the faults in principle inherent in the Covington machine are, however, faithfully preserved.



No. 10. Heyl & Patterson Machine, Front Elevation.



No. 11. Heyl & Patterson Machine, Side Elevation.

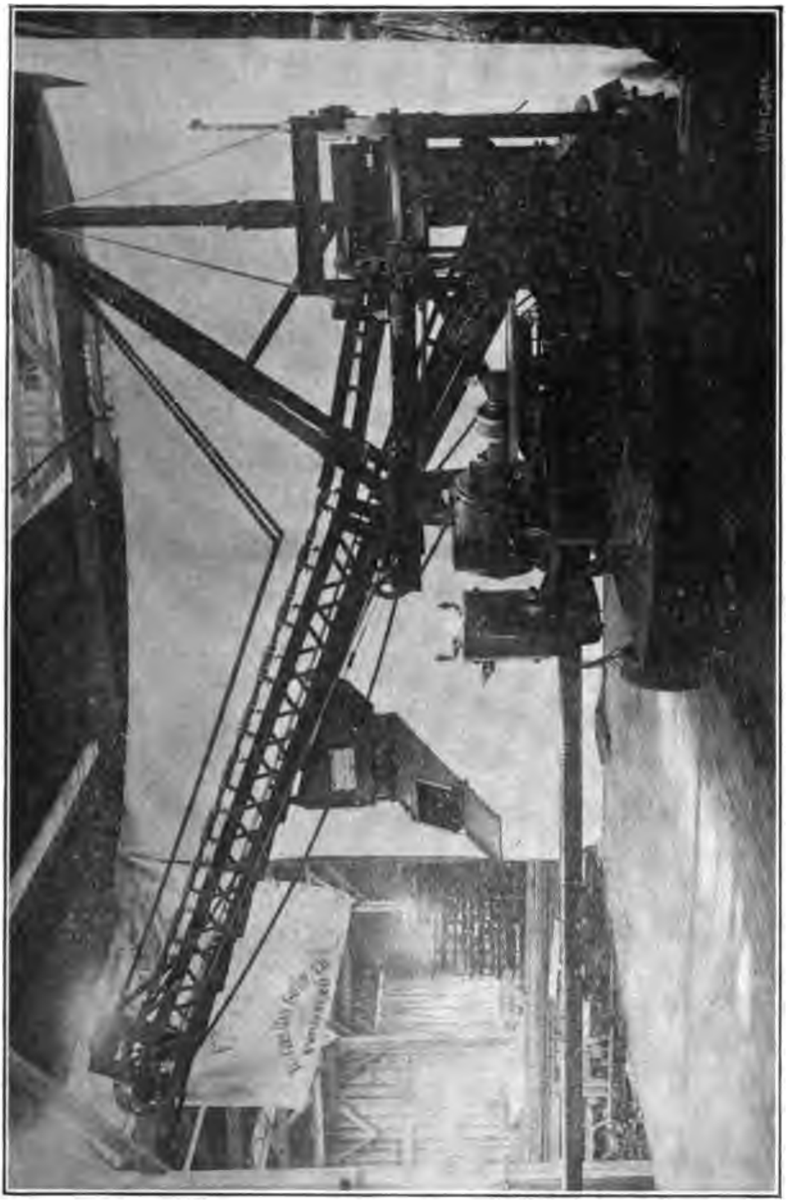
Both the Covington and the Heyl & Patterson machines have a practically rigid wheel base over 20 feet long, so that a turntable is necessary to transpose them for operation on both sides of a block of ovens.

As the Heyl & Patterson machine is so nearly like the Covington in design, no extended description will be necessary. The track gauge and the height of rail below oven seat have been exactly duplicated, and it would seem that the machine has been designed as a substitute for the Covington, on the very yards it now operates on.

THE MARMAC COKE DRAWING AND LOADING MACHINE.

The Marmac machine is a direct result of the faults of the Covington. It was invented jointly by Mr. R. L. Martin, Jr., of the Bessemer Coke Company, and the writer, and designed by the writer. *Only one machine has been placed in service*, but others are now under course of construction.

In general principles, it is similar to the Covington, to the extent of having an extractor and a conveyor. The extractor is fitted with a rack driven ram and the Smith shovel. Here the resemblance ceases. The method of driving and swinging the ram, and of driving the track wheels, is new. The conveyor is unique. All the prominent features of this machine are protected by patents. No better description of the machine can be given than some extracts from the specifications, on which these machines are sold.



No. 12. The Marmac Machine, from Extractor End.

This machine consists of an extractor and a conveyor, each separately and independently mounted on its own truck and connected to each other by a draw bar. The extractor draws the coke from the ovens, from whence it falls on the conveyor. The conveyor receives the coke from the extractor and delivers the same to the yard or a railroad car.

Upon the extractor truck are mounted two motors, one for reciprocating the ram, and another for swinging it. Upon the conveyor truck is mounted a single motor, which is connected at will either with the conveyor, or to the track wheels on conveyor truck, so as to move the whole machine along the track. These three motors provide power for the four motions of the machine, viz.: The reciprocation of the ram, swinging of same, driving the conveyor, and moving the machine along the track. It is to be noted that all these motions are driven by friction clutches, so that there is a yielding point between the driving motor and the driven machinery in each and every case. Machines to deliver coke into a car on a track 40 ft. from face of ovens. (This distance can be increased or diminished.)

The track in front of the ovens, on which the machine runs, is tilted to the same slope as the bottom of the ovens, in order that the ram may work parallel therewith. The extractor truck consists of steel framing, mounted on four track wheels. The side beams of truck are 15 in. at 42 ℔s. per foot. The intermediate cross channels are 15 in. at 33 ℔s., rigidly framed into the side beams. Entirely covering these beams and channels there is a ⅜ in. steel plate, forming a platform to receive the operating mechanism. The axles extend through the web of the beams and are supported in steel waste-packed axle boxes, similar to standard railway type, and having brass bearings. The axles are 4 in. diameter, cold rolled steel, and axle brasses are 12 in. long.

The track wheels for extractor are cast steel, bored and fitted to axles, but are not finished on the treads.

"The wheels on outside rail are 20 in. diameter by 3 in. face, with double flanges.

No. 13. The Marmac Extractor. Ram Carriage swung to extreme left.

"The axles at this side of truck are reduced to 3¾ in. diameter, wheels bored to suit the same and clamped to axles with a washer and a 2 in. nut.

"The track wheels on inside rail are 20 in. diameter by 8 in. face, without flanges. They are bored to a neat fit on axles and fastened to same by 1¼ in. pins.

"This construction puts all the strain of the ram action on the outside rail.

The truck also depends for accuracy of alignment solely on the outside rail, and as the double flanges on outside track wheels are a practically neat fit on this rail, and the wheels on the other side of truck are plain, a much more accurate alignment of the truck on the track is secured by this construction.

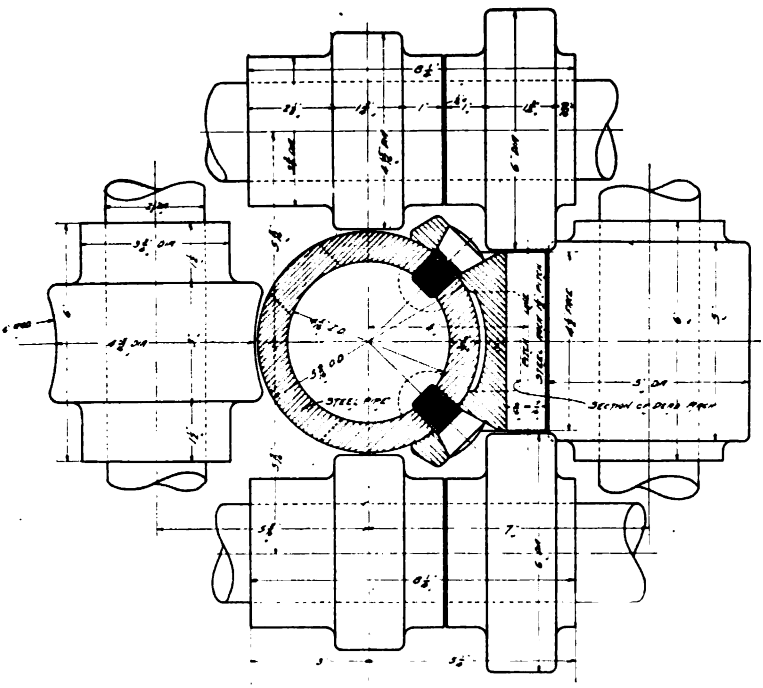
"The horizontal swinging of the shovel in the oven is obtained by swinging the ram about an imaginary center, practically at the center of the oven door. In order to obtain this action, the ram with its driving motor and carriage, is mounted on a pair of curved guides, rigidly riveted to the top plate of truck. The rear guide, taking the thrust of the entering ram, is composed of a 6x6x1 in. rolled steel angle, and the front guide receiving the pull of the outcoming ram consists of a 6x6x¾ in. angle.

"Mounted above these angle guides is a heavy steel casting, which serves as a bed plate for the motor and gearing, and as a guiding frame for the ram. At the extreme outside corners of this casting there are two steel rollers, mounted on vertical pins, the same engaging the curved angle guides on truck. These rollers constrain the ram to move at all times in lines radiating from the imaginary center at the oven door.

"Just inside of these rollers are two other rollers mounted on horizontal pins, which roll on the top plate, between the curved guides, and carry the major portion of the weight of ram, motor, gearing, etc.

"The motor and gearing are arranged on the opposite sides of the centre line of the ram, in order to distribute the weight equally on these two rollers.

"In order to support the weight of ram when the same is near the oven door, there is provided a roller directly under the centre line of ram, and approximately at the outside edge of truck, the same being supported by a steel carrier having interposed between it and the main guide casting, a pair of strong helical compression springs. At the front and rear ends of the ram guide casting there are four rollers surrounding and guiding the ram, one of these being under, one over and one at each side of same.



No. 14. The Marmac Machine. Section through Ram and Guide Rollers.

"The ram is composed of a piece of double extra strong steel pipe $5\frac{9}{16}$ O. D. by $4\frac{1}{16}$ I. D. by $\frac{3}{4}$ in. thick.

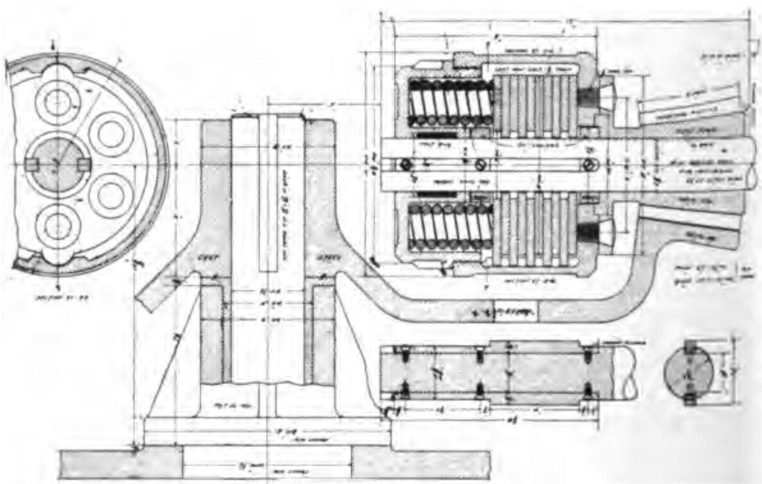
"At one side of this pipe there is riveted a cast steel rack $4\frac{1}{2}$in. face, made in seven sections, each 3 feet long.

These rack sections are fastened to the pipe by ⅞ in. taper threaded boiler patch bolts 6 in. pitch, with countersunk heads, cold riveted into flanges on rack sections. Both ends of ram are turned to fit the shovel, so the ram may be reversed when worn.

The ram is reciprocated by a 25 H. P. 220 volt Westinghouse No. 48 series wound motor, railway type, fully enclosed, with single hand reversing controller of the drum type. Motor and controller are water and dust proof.

The armature pinion is of forged steel 5⅓ in. pitch diameter, 16 T. 3p. 5 in. face, and is loose on the armature shaft.

The armature shaft is extended beyond the pinion to carry a special multiple disc dust proof friction clutch. One member of same is keyed to armature shaft and the other bolted to the flange on the pinion.



No. 15. The Marmac Machine.
Special Spring Adjusted Multiple Disc Clutch on Ram Drive.

This clutch is fully enclosed. The friction surfaces are of metal, running in oil, and the clutch can be adjusted up to its capacity, to carry any desired load.

This construction makes the reciprocation of the ram practically "fool proof," as the operator cannot injure the machinery either by runing the ram too far into the oven or back against the stop.

It also minimizes the destructive action caused by the hammering of gear teeth on the reverse of motor.

The main driving gear for ram is a cast steel bevel gear 43 in. pitch diameter, 129 T., 3 pitch 5 in. face. This gear is mounted on the top of a 3¼ in. diameter vertical shaft, supported in two brass bushed cast steel dead eye bearings, flanged and bolted to main guide casting. Between these bearings is located the cast steel double shrouded pinion driving the ram. This pinion is 6¼ in. P. D., 13 T., 5 in. face, with ¾ in. thick shroud extending to the top of teeth at both ends.

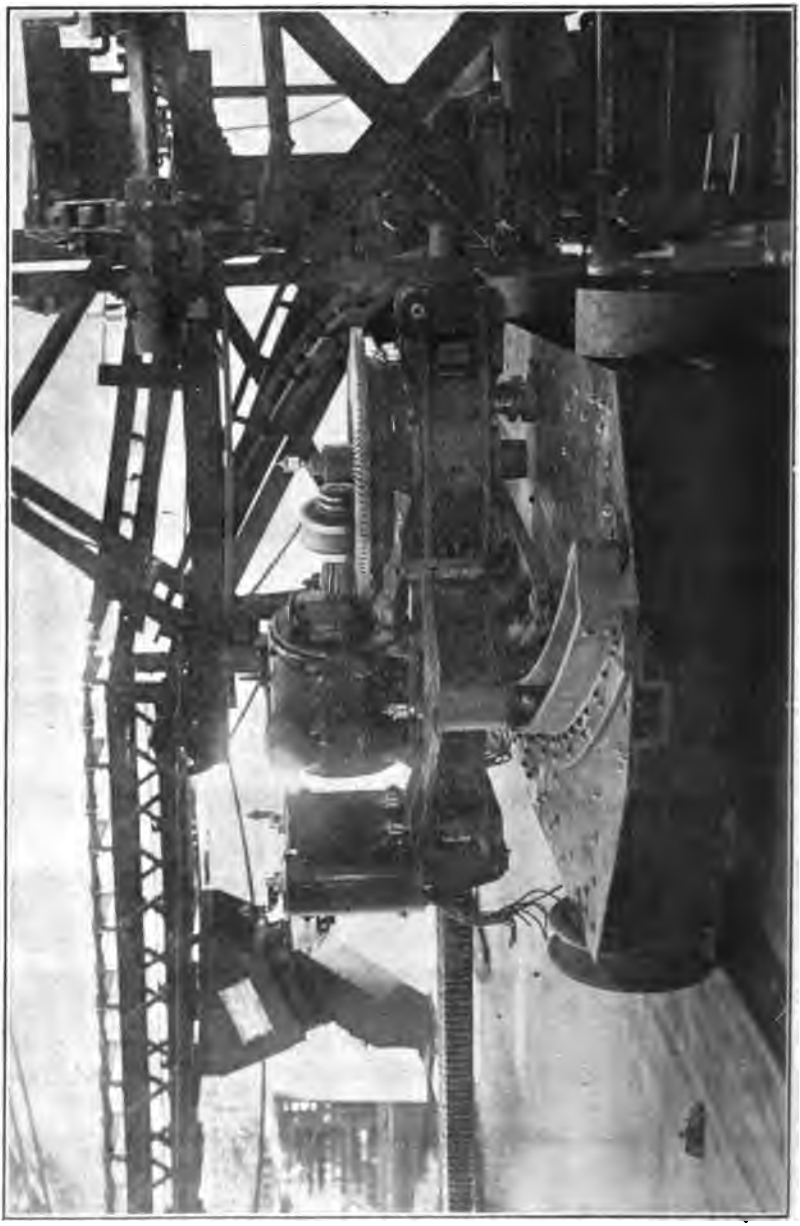
The motor for swinging ram is a 3¼ in. H. P. type "K" Westinghouse crane motor, 220 volts, fully enclosed, with single hand reversing controller.

This motor is back geared by a pair of cut spur gears, 3 in. and 14 in. diameter; the back gear shaft carries a cast steel bevel pinion, 19 teeth, 6⅞ in. pitch diameter, meshing with a cast steel bevel gear 83 T. 2 ft., 5¾ in. pitch diameter, 2½ in. face, on a vertical shaft extending up through top plate of truck.

On the top of this vertical shaft is a cast steel sprocket wheel, 6 in. diameter, 7 teeth, engaging a piece of No. 17 "roller pin" chain. This chain passes around an Idler sprocket at the other end of truck and both ends of the chain are fastended to pins projecting from the under side of main guide casting, with adjustments to take up the stretch of the chain.

This chain is a duplicate of that used to drive the conveyor. By this mechanism the carriage or guide frame for ram can be rotated to any point within its travel by the simple movement of the controller handle.

This drive by the inclusion of a special dust proof friction clutch, also renders the operation of the swinging motion "fool proof," as no harm can be done to the machinery by



No. 16. The Marine Machine. Ram Carriage Central Conveyor Boom in Low Position.

swinging the carriage at full speed against the stops provided to limit its travel.

The speed of chain swinging the carriage is 42 feet per minute.

As it is necessary to shift the railroad car being loaded along its track, to keep the same in proper relation to the coke drawing machine, as it moves along in front of the ovens, we have provided a simple means of doing this by power taken from the ram motor.

This consists of a cast steel hook riveted to the rear end of ram, over which can be thrown a rope of chain, the same being led around a snatch block or a snub post to car.

The shovel is of cast steel in the shape of a curved wedge, the inside metal being cored out so as to leave 1½ in. thickness of metal all over the outside.

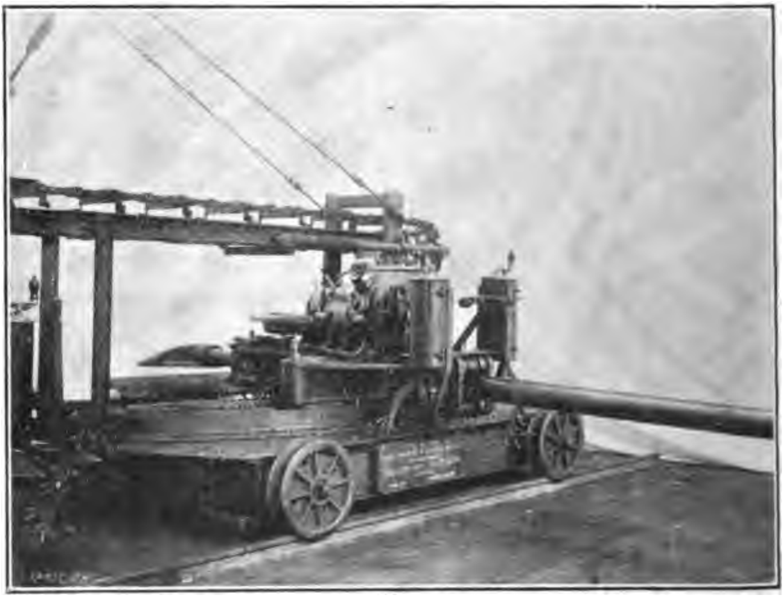
This shovel has a boss at the rear about 9 in. long, the same being bored slightly smaller than the diameter of the ram pipe, which is turned to be a tight fit therein, and fastened by two 1½ in. tight bolts.

The shovel is 40 in. long by 15 in. wide, by 8 in. thick at the rear.

To the inside of extractor truck, between ram and rear truck wheel, there is provided a cast steel swinging support for the overhanging end of conveyor. This support is hinged so that it can be swung sideways against truck frame when the extractor is being turned on turntable, for instance, and is also provided with a vertical adjustment by which it can be set up to sustain the weight of the outer end of the conveyor. The tail end of the conveyor is to extend back to include the previous oven so that the coke remaining in the oven when the machine leaves it, may be drawn directly into the conveyor by hand.

This construction makes this end of the conveyor rigid under the falling coke. At the same time the conveyor is not fastened in any way to the extractor truck, so that if desired the extractor and the conveyor may be separately turned on a short turntable about 10 ft. long.

The axle bearings for extractor are lubricated by waste packing in axle boxes, in the usual manner. The motor bearings are self-lubricating. All other bearings, including vertical drive shaft and all pins for weight and guide rollers, are lubricated internally, from compression grease cups, the lubricant being forced from the inside of the bearings outwards, thus preventing the coke dust from entering and destroying the bearings.



No. 17. The Marmac Extractor.

The materials specified in the above construction of extractor are all of the very highest grade and the best adapted for the purpose. The truck wheels are cast steel, the axles are cold rolled steel, axle bearings are brass, frame of the car is soft O.H. structural steel, carriage for ram is cast steel, bearings for main drive shaft are bronzed bushed. All the pins for rollers are steel, fastened to casting, with loose roller mounted on pin.

All the guide rollers for ram are steel, the motor pinion is forged and the main gear is cast steel. The rack pinion is cast steel.

The total weight of the extractor, including two controllers and resistance, for the two operating motors, is about 18,000 pounds.

The conveyor and its supporting structure are mounted on a truck having the same gauge and wheel base as the extractor. Gauge is 7 ft. in centre to centre of rails, wheel base is 8 ft.

The distance between centres of adjacent axles on extractor and conveyor is 7 ft., making the total wheel base of combined trucks 23 ft.

The conveyor truck is built up of structural sections, having 4 in. cold rolled steel axles, with double flanged track wheels on outside rail and plain track wheels on inside rail, the same being made from the same patterns as track wheels for extractor, but the material being cast iron.

The drive for conveyor and for the track wheels of conveyor truck is by a 12½ H. P. Westinghouse 220 volt, fully enclosed, shunt wound motor. This motor is built on No. 48 frame and is mechanically and electrically interchangeable with the motor on extractor, in all respects except the field coils and the pole pieces. The armature, commutator, bearings, etc., are exact duplicates. The motor is set on a steel plate on top of conveyor truck at the extreme corner of the frame.

This is done in order to utilize to the greatest possible degree the weight of motor for balancing the overhanging of the conveyor.

The armature shaft of conveyor motor is extended beyond the centre line of truck, its outer end being supported in a ring oiling pillow block mounted on a cast iron stand. This shaft carries a cast-steel machine-cut pinion, 4⅓ in. P. D., 13 T., 3 in. p., 4½ in. face, meshing with a split cast iron spur gear 30⅔ in. P. D., 92 T., 4 in. face, the same being mounted on a 2¼ in. shaft running the length of the truck.

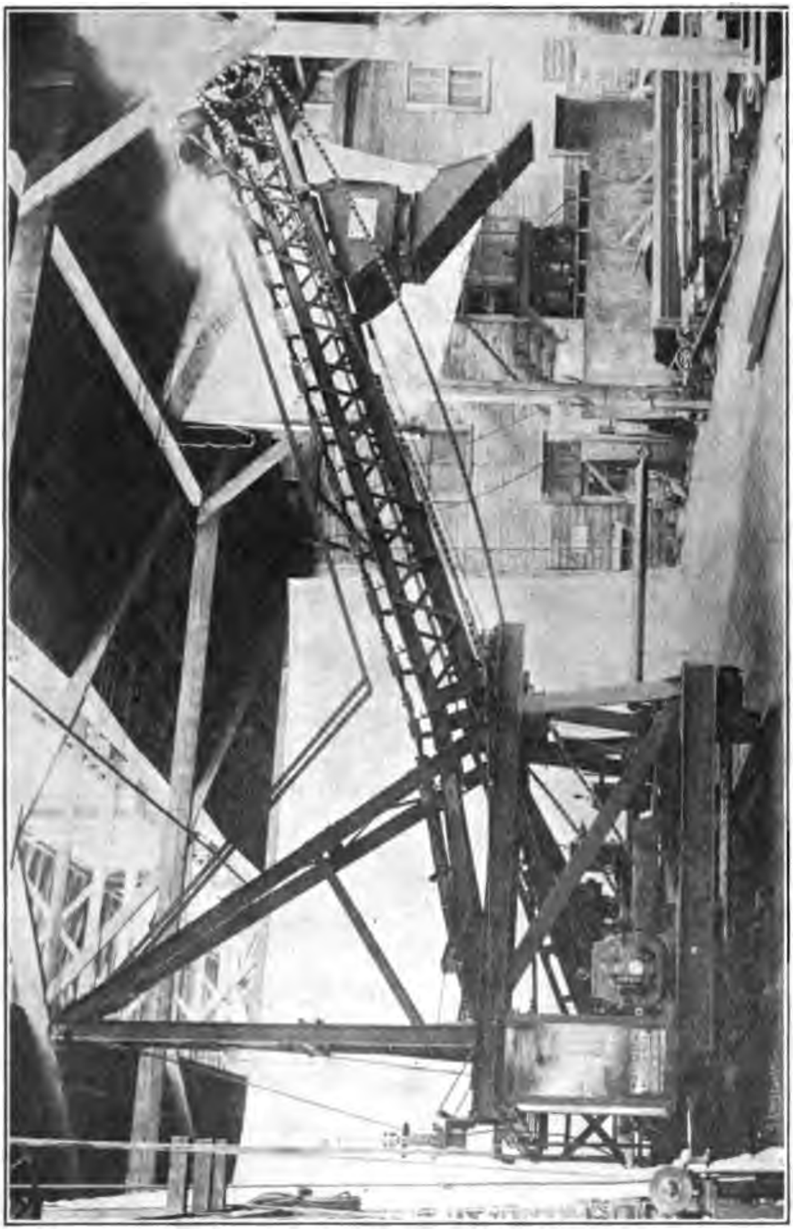
This shaft is supported in four bearings, one at each end being a flanged babbitted dead eye, bolted to end channel of truck. Between this bearing and worms there are ball thrust bearings. There are also two rigid pillow blocks located at the central portion of the shaft, these being supported by cross channels.

This shaft carries a pair of cast-iron triple-threaded worms 5¾ in. P. D., 2 in. p., 8 in. long, the same being located directly over and meshing with two cast steel worm wheels 15¼ in. P. D., 4 in. F., 2 in. p., 24 teeth, each of these being keyed to an axle. This arrangement drives all four wheels on the conveyor truck.

The drive for the conveyor proper is taken from a loose cast steel sprocket 10¼ in. P. D., 12 T., thence by No. 17 "roller pin" chain to a 20¼ in. P. D., 24 T., cast steel sprocket on a countershaft located about at the pivot point of overhanging conveyor arm.

This countershaft carries at its opposite end a cast-steel sprocket 8¼ in. P. D., 7 teeth, from which the drive is carried by No. 14 "roller pin" chain to a cast steel sprocket 30 in. P. D., 27 teeth, located on the 3 in. head shaft of conveyor, the same being mounted at the extreme end of the overhanging arm. The speeds of these separate shafts are as follows: Armature shaft 900 R. P. M., drive shaft for track wheels 130 R. P. M.; conveyor countershaft 65 R. P. M., conveyor head shaft, 16.6 R. P. M. Speed of conveyor, 100 feet per minute. Speed of machine along track, 84 feet per minute. By means of a pair of friction clutches, located on the opposite sides of cast iron spur gear, the power is taken at will either to the track wheels or the conveyor. The motor is controlled by a reversing controller, so that the machine can be run in either direction upon the track by reversing the motor.

In addition to the above, there is a ratchet device between the driving sprocket on head shaft of conveyor, which will transmit power in one direction only, so that it is impossible for the operator to reverse the conveyor, no matter which way the motor is run.



No. 18. The Marmac Machine. Conveyor Boom in High Position.

Main supports for conveyor consist of structural steel sections, mainly 6 in. channels, forming a tower.

The overhanging framework at head end of conveyor is hinged to the supports so that it may be lowered from the extreme high position, to approximately a level position without interfering with the operation of the conveyor.

This raising and lowering is effected by a worm-geared manually-operated winch, operating a 3/8 steel wire rope, reeved round suitable sheaves as shown.

The worm gearing for winch gives a powerful, slow motion, enabling one man to raise or lower the conveyor and forming an automatic lock for any position.

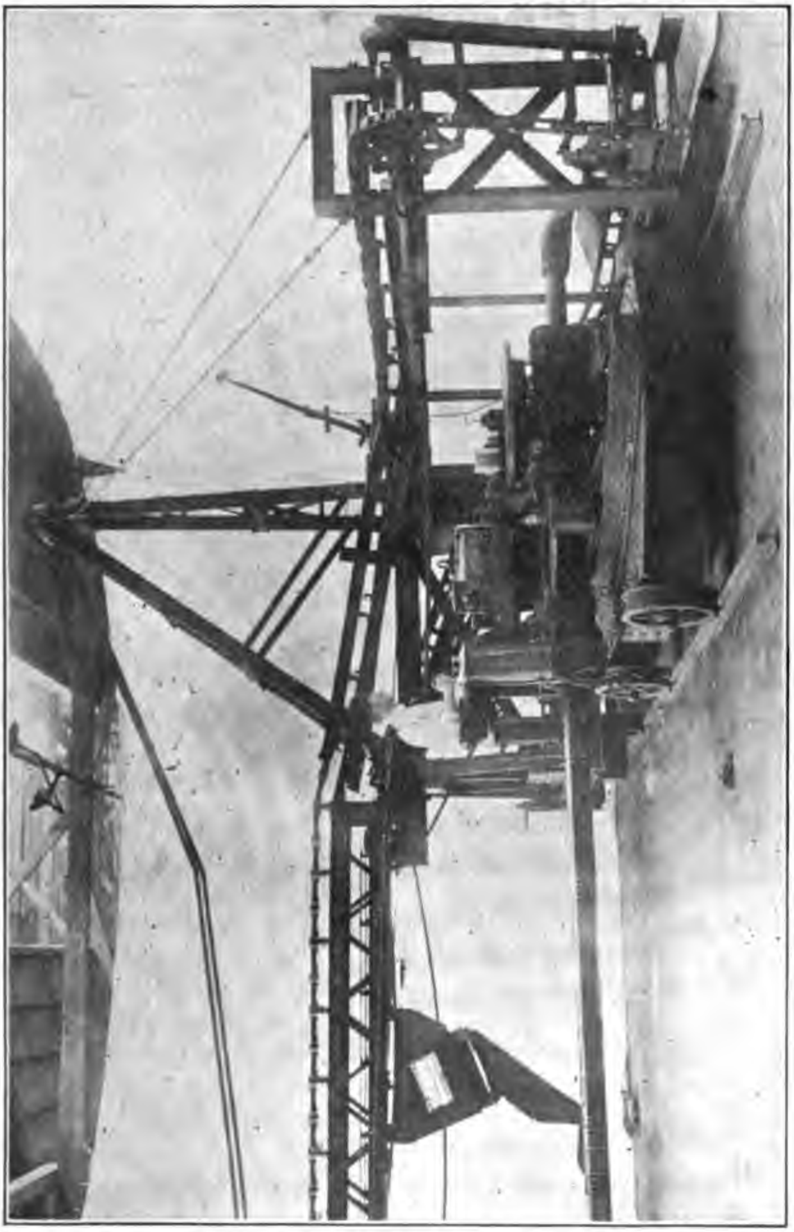
The conveyor proper consists of a single strand of special double-jointed chain described hereinafter. The same having steel flights 4 in. high, extending from one side only of the chain.

This chain is driven from the outer end of overhanging arm and drags the coke with a continuous smooth motion from the oven door to the point of delivery, with no intermediate fall or change from one conveyor to another.

The general contour of the conveyor is approximately that of an acute angled triangle with a sprocket at each corner thereof, the same being located in two vertical planes with a right angled curve connecting them. The lower strand of the conveyor is the working strand. It extends horizontally from a point under the oven door for a distance of about 10 ft. and then rises on a continuous even grade of 5 in. per foot to the delivery end, passing around a curve of 8 ft. radius.

The return strand of the conveyor runs parallel to the working strand from head shaft back to pivot point of overhanging arm and from thence around an 8 ft. radius curve at a lesser grade than the working strand to a horizontal line above the oven door, from whence it drops vertically over the tail sprocket to the Idler sprocket at the point of beginning.

Beginning at the pivot point and extending about 10 ft. on the bottom of conveyor trough, there is a screen composed



No. 19. The Marmac Machine, showing Position of Operator.

of 2x⅝ in. screen bars, spaced ⅝ in. apart, for the separation of the ashes and fine dust from the coke.

From the end of this screen to the end of the conveyor the bottom of conveyor trough is composed of continuous hinged drop doors, about 2 ft. square, permitting of the delivery of the coke at any one of these doors. This feature enables the product to be delivered either into the yard for storage or over the end of the conveyor into railroad cars. It also permits of the conveyor delivering into railroad cars on a curved or inclined track, which is at a varying distance from the front of the ovens, or to work successfully in two or more yards in which the track is at different distances from the ovens.

In connection with the overhanging arm of conveyor, there is a traveling trolley chute made of light steel plate and operated by small winch on conveyor truck. This chute can be placed under any of the drop doors, or at the extreme end of the conveyor. It also can be swiveled on a vertical pivot, so as to deliver at any angle, to the yard or a car.

The conveyor chain is specially designed, consisting of alternate cast steel links and rolled bar links 6 in. pitch.

The pins for the articulation of the chain around the sprockets are made of 1¼ in. cold rolled steel, shouldered and riveted at one end into the bar links and shouldered and clamped by a nut at other end to bar links. By removing these nuts the chain is made detachable.

The cast steel links are each made in two parts, with a vertical joint pin connecting same.

The flights are spaced 24 in. centres, being bolted to a bracket attachment extending from one side of chain and fastened to the flights by two ⅝ in. bolts.

This chain is composed entirely of cast or rolled steel, with ample wearing surface in the pins.

The bearing area of pins is also as well protected against dust as it is possible to make same.

The sides of conveyor trough, except boom, are com-

No. 20. The Marmac Machine, showing Shovel and Curve in Conveyor.

posed of 8 in. channels, and to the outer one is fastened a ⅛x12 in. wearing plate.

There are a number of 8 in. diameter cast iron, babbitted rollers placed around the curves.

In addition to these rollers there are several of the same sized rollers placed under the chain and a couple on top of it at the vertical curves.

The weight of complete conveyor and operating mechanism is about 22,000 lbs.

The electrical equipment of this machine consists of a 25 H. P. series wound motor, a 12½ H. P. shunt wound motor, and a 3¼ H. P. series wound motor, as before specified; all of Westinghouse make. All have drum type controllers. The first two of these motors are mechanically and electrically interchangeable in all respects, except the field coil and pole pieces. All the motors are fully enclosed and water and dust proof. Trolley is of the standard Larry type.

ADVANTAGES CLAIMED BY THE MANUFACTURERS FOR THE MARMAC MACHINE.

First—It will draw more coke per working day. As the coke is all removed from the oven at one setting of the machine on the track, no time is lost in moving machine to reach coke at sides of ovens.

Second—It saves one operator. The swinging of the ram by power dispenses with the "spell hand."

Third—Low construction. The machine is designed to operate on a track of which the top of rail is 25 in. below the oven door. This saves a foot of grading on old plants and a foot of masonry on new ones, and the ovens are adapted to be hand drawn when necessity requires.

Fourth—The coke is conveyed with one continuous smooth motion from oven door to point of discharge, with no intermediate transfer, thus decreasing breakage.

Fifth—Coke can be delivered from the conveyor at any point between a distance of about 16 ft. from ovens and the end of conveyor, thus making the machine adapted to deliver to railroad cars on a curved or inclined track not parallel to ovens.

Sixth—The materials of construction are mostly steel—cast iron is eliminated in all the important parts—the construction is simple, accessible and very strong, *insuring low maintenance charges and extreme reliability.*

Seventh—The slipping connections between motors and the driven parts render the whole machine practically "fool proof."

PERFORMANCE OF THE MARMAC MACHINE.

Owing to unusual and difficult conditions of operation at the Griffin plant, and to the fact that the machine was "butchered" somewhat during a period of preliminary experimenting, the first machine has not yet reached its expected capacity of 50 ovens per 10 hours.

It has, however, drawn more ovens in its first three months of operation than any previous "first machine" ever built. Much credit for this fact is due to Mr. Geo. L. Humphreys, superintendent at Griffin plant. During July, 1907, the machine drew 863 ovens, or an average of 34½ per day worked. For August the total was 917 ovens, an average of 35¼ per day worked. For September the total number of ovens drawn was 715, or an average per day worked of 30.

In October, 1907, the machine drew a total of 1004 ovens in 27 days, or an average per day of 37¼.

The machine has drawn three consecutive ovens in 20 minutes.

The greatest number of ovens drawn in any one day was on September 4, 1907, when 59 ovens were drawn.

COST OF INSTALLING COKE DRAWING MACHINES.

The cost of installing machines will depend much, of course, upon local conditions. The doors on the ovens for machine drawing should be not less than 42 in. wide and, so far as the machine is concerned, a greater width would be of advantage. As the hand-drawn ovens rarely have doors over 2 ft. 6 in. wide, all the oven doors must be widened.

I present below an estimate recently prepared for a prospective customer, showing the probable cost of installation of the machine, track, wiring and changing 100 ovens. The yard at this plant is unusually high, being in many places only 18 in.

below oven seat, so that the allowance for grading could, in many cases, be cut out. As a whole, the estimate is liberal:

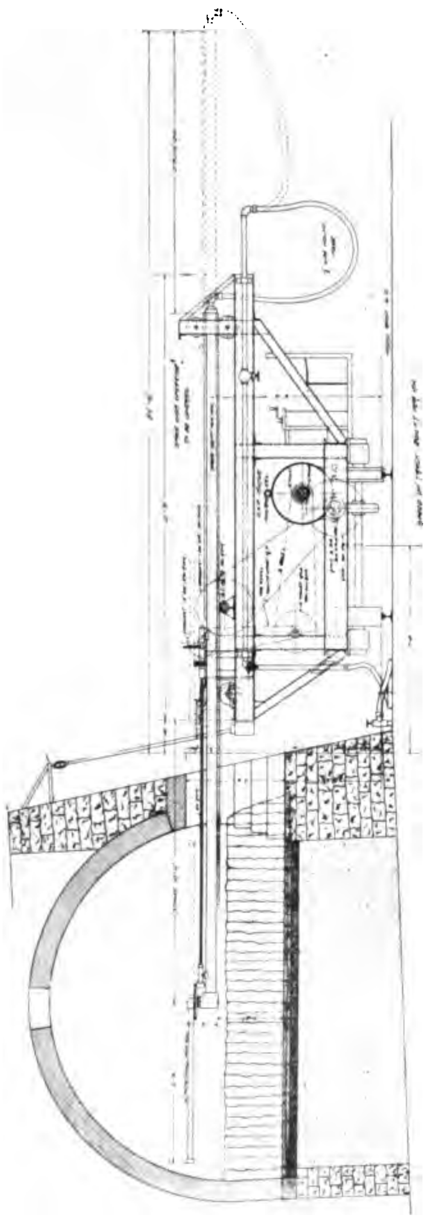
1500 ft. 80 lb. T rail—40000 lb. at $30.00 G. T.	$ 536.00
2300 ft. 60 lb. T rail—46000 lb. at $30.00 G. T.	611.00
950 R. R. ties 9 ft. lg., at 75c	713.00
Laying 1900 ft. of track, at 50c	950.00
Bonding track	50.00
TROLLEY WIRE.	
2000 ft. No. 00 grooved trolley—800 lb. at 30c	240.00
50 hangers, erected	50.00
6-25 foot poles erected	60.00
1000 ft. of span wire	25.00
Insulators, etc.	25.00
Labor erecting trolley wire	60.00
CHANGING OVENS.	
Labor changing doors, at $10.00	1000.00
C. I. jambs for doors, at $11.00	1100.00
C. I. door plates 200 lb. each, at $5.00	500.00
Brick, etc.	200.00
Grading yard about 2000 cu. yds. at 50c	1000.00
Total	$ 7120.00
Cost of Coke Drawing Machine, erected	6630.00
Grand Total	$13750.00

Although this paper was originally intended to be confined to coke drawing machines, it has been thought well to supplement it by a brief description of some other machinery for use at the ovens, and so nearly related to the coke drawing machines that they are practically in the same family.

THE MACFARREN QUENCHER.

Early in his acquaintance with the coke drawing machine, the writer was struck by the advantage over hand drawing due to getting the coke out of the ovens in less time, which is entirely independent of the saving in cost over hand labor.

Pressure of other business and the necessity for getting down to details on the drawing machine drove this matter from his mind, but it was forcibly brought back by a recent conversation with Mr. E. J. Taylor, Chief Engineer of the Pittsburgh Coal Co.



No. 21. The Macfarren Bee Hive Oven Quencher.
Original design by the writer.

Mr. Taylor stated that in studying the operation of the Wynn plant of the Frick Coke Co., which is one of their latest plants, being designed for machine drawn coke exclusively. he was impressed by the fact that while the machine removed the coke in about 15 minutes as against three hours by hand drawing, none of this saving in time was utilized, owing to the fact that the ovens were still being watered by hand with a hose in the same old way, and that in order to keep pace with the drawing machine, the waterers had to start a long way ahead.

In short, Mr. Taylor thought a good watering device was needed. Some days later he had a proposition on the "Macfarren Quencher," shown in outline in the illustration.

The purpose of this machine is to water the coke in the ovens just prior to drawing the same.

The advantages of the machine over hand-watering are as follows:

First—A more accurate distribution of the water over the body of coke. This is obtained by the automatic action of the machine and does not depend on the operator.

Second—Greater speed. By the use of larger pipes, an oven can be quenched thoroughly in a much less time than by the hand method.

Third—Saving of heat.

From the above statements it will be seen that the machine, by reason of its accuracy and speed, can water ovens about as fast as the coke drawing machine can draw them, and can, therefore, be operated no more than one or two ovens in advance of the coke drawing machine. This means that the ovens are not watered until the exact time the machine is ready to draw them and results in a large reduction in the loss of heat over having the ovens watered considerably in advance of the drawing machine.

If the ovens are promptly drawn after the watering and promptly charged after the drawing, the three processes of watering, drawing and charging can all be accomplished inside

of an hour, with the result of permitting the use of heavier charges and a corresponding increase of production.

The machine consists of a traveling truck running on the coke drawing machine track and carrying a bar adapted to be extended into the ovens above the coke. This bar is hollow and contains water. The forward end of this bar is provided with a swinging spray pipe, which rotates about the centre of the oven as a centre and sprays the water over all portions of the charge of coke.

The water supply is obtained from plugs along the front of the ovens, as usual, by a hose connecting to a pipe along the machine. This hose would be of sufficient length to water about four ovens without disconnecting from the plug.

The water is carried by this pipe to the rear of machine, through a valve under control of the operator, to a second hose, which connects with the rear end of the ram bar and hangs in the form of a loop to permit of the horizontal motion of the bar.

The ram is composed of a piece of 4 in. extra strong steel pipe, having a stroke of 10 feet, obtained by a rack and pinion underneath the bar. The ram is supported and guided by rollers, as shown. The lower rollers are double flanged, to prevent displacement of the ram bar, and the upper roller at rear of machine contains a groove, embracing a flat bar riveted to upper side of ram to prevent rotation of the same. The pivot head consists of a casting screwed over the end of the ram pipe, having a stuffing box at its upper end. Through this stuffing box there extends a hollow brass pivot pin, with a right angle bend at the top, in which is screwed the spray pipe. The water enters this pivot pin through a series of slots opposite the ram pipe. Just under the spray pipe there is a brass bevel gear, 16½ in. P. D., 78 teeth, 2 in. face, bolted to the pivot. This gear is driven by bevel pinion 3¼ in. P. D., 15 teeth, also of brass, on the end of a 1 in. shaft supported in bearings on the ram pipe.

The spray pipe being power driven at the rate of about 10 rotations per minute, insures a positive and even distribu-

tion of the water over the coke. The holes in the spray pipe are of uniform diameter and uneven spacing, being closer at the outer end of the pipe and further apart toward the inner end, in such proportion as will give a uniform quantity of water per unit area of coke passed over.

THE MACFARREN LEVELER.

Since his first acquaintance with coke ovens and drawing machines the writer has had an idea that a machine could be designed to level the coal in the ovens after charging. This idea was strengthened by a conversation with Mr. H. Clay Lynch, Assistant General Superintendent H. C. Frick Coke Co., some time ago, when the latter suggested that the writer design such a machine. Mr. Lynch's idea was not so much to save money directly over hand labor, as to secure more accurate leveling of the coal.

Coal, in the process of coking, demands a certain length of time to coke. For each increment of time available there should be an increment of coal charged. If not burned long enough, the oven contains raw coal; if burned too long, part of the fixed carbon is burnt away, in other words, a portion of the coke is reduced to ash, which is a loss in either case. Now, if the oven be not properly and uniformly leveled it is evident that the high spots will have raw coal under them and the low spots will have an excess of ash over them. As the work of leveling by hand is paid for at piece rates—12½c per oven—the natural tendency of the laborer is to get as many oven doors bricked up as possible, which is what shows on the pay roll. It is, of course, desirable to save money directly on the operation, which it is thought can be done, but from the above standpoint, the most important advantage to be gained is the uniformity and improvement in the product.

It was hoped to be able to complete designs for this machine in time to include an outline of it in this paper, but time has not been available for it. However, the writer's idea for such a machine may be briefly described. In general arrangement, the machine would be much like the quencher,

No. 22. Long Oven Plant of the Connellsville Central Coke Company, showing Pusher.

No. 23. Long Oven Plant of the Connellsville Central Coke Company, showing Quenching Machine.

only more powerful. It would run on the coke drawing machine track and would have a hollow bar adapted to be projected into the oven, similar to the quencher. At the end of this bar there would be a pair of curved arms pivoted underneath the bar and rotated about the centre of the oven. These arms, or flights, would be driven by a shaft running through the hollow bar, and connected to the flights by enclosed bevel or worm gears. The apparatus would be projected into the oven with the flights parallel to the bar, and shoved through the pile of coal until the pivot of the flights was at the centre of the oven. The slow rotation of the flights around the centre of the oven would then spread the coal to an even thickness, the curve in the flights acting to work the coal from the centre of the oven toward the outside. The bar would have a vertical adjustment to permit of leveling for different charges.

THE RECTANGULAR COKE OVEN.

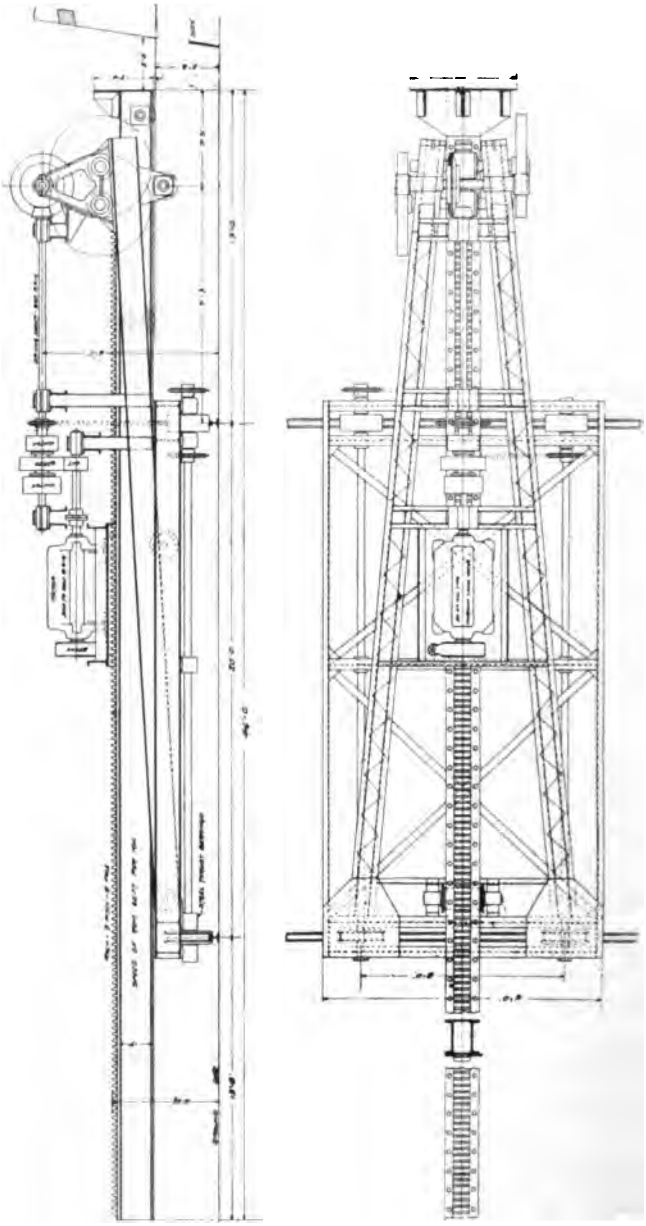
As before stated, ovens of this kind are now being experimented on extensively in the Connellsville region. The H. C. Frick Coke Co. and Mr. W. J. Rainey have several experimental ovens. This form of oven was revived by Mr. T. J. Mitchell, General Manager of the Rainey interests.

The Connellsville Central Coke Co. have under construction 100 ovens of the "Mitchell" type, after designs of their manager, Mr. John C. Neff. These ovens are approximately 5 ft. wide, being tapered sideways to a slight extent and are 30 ft. long inside the doors.

Machinery for pushing out the coke, leveling the coal, watering the coke in the ovens, and conveying the coke from ovens to railroad cars has been ordered, there being a separate machine for each of these operations.

The pusher, leveler and quencher use a common track in rear of the ovens and the conveyor a separate track at the front.

The writer is not a coke expert and does not venture a prediction on the success of these ovens, which depends on



No. 24. Pusher for Long Ovens. Original design by the writer.

many things, including quality and yield of coke, maintenance of ovens and machinery, fixed charges, etc.

He, however, will state positively that the labor item will be greatly reduced even in comparison with machine drawn bee-hive ovens and that probably the coke will be larger as shipped and present a better appearance in the car.

This statement will be apparent from the simplicity and speed of the machinery.

PUSHER FOR RECTANGULAR OVENS.

The pusher itself is an old device, it having been extensively used on by-product ovens of the Otto-Hoffman type.

The design shown possesses some points of novelty in the manner of carrying the thrust to the rear track rail and in the division of the drive to two pinions in engagement with the rack.

The machine has power to push out an oven full of coke in thirty seconds after striking the same.

It is conservatively estimated that this machine could push ten ovens per hour, or could take care of a 200-oven plant, with 5 ft. by 30 ft. ovens working ten hours per day.

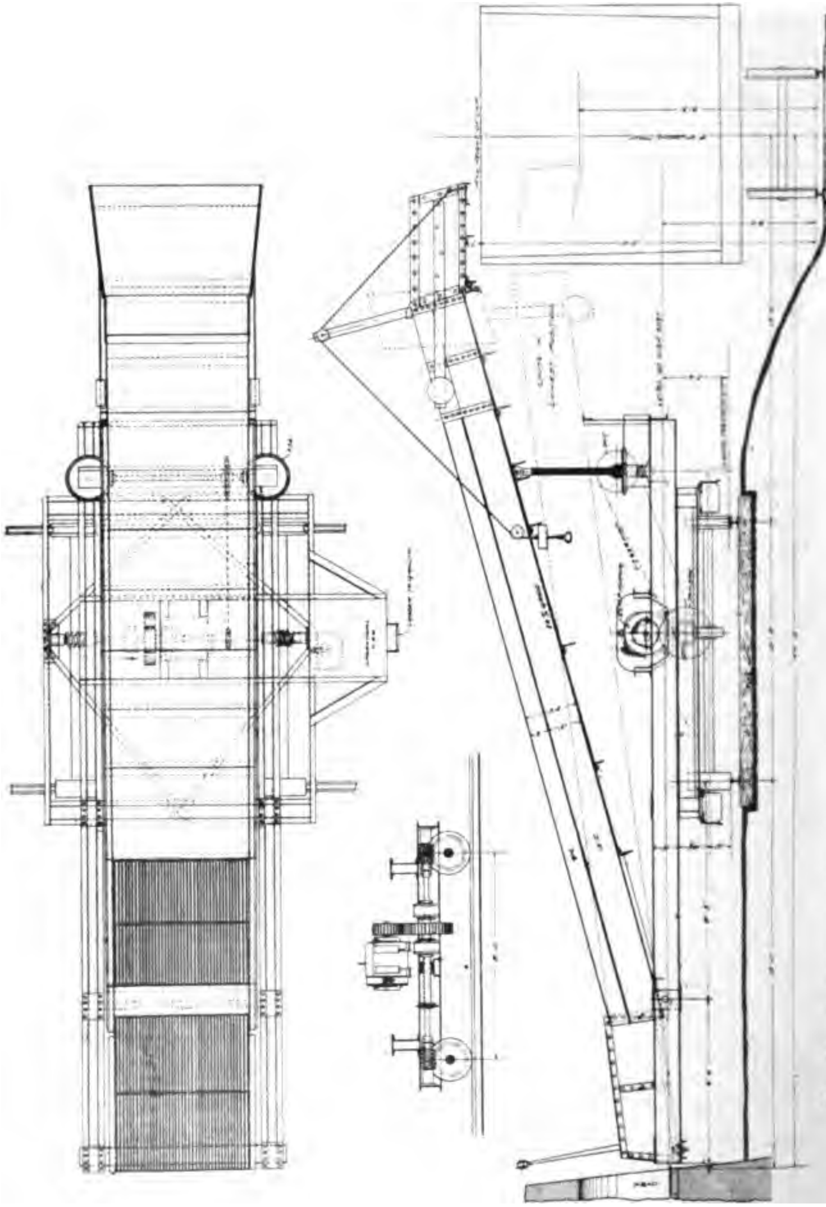
This is equivalent to about a 250 oven bee-hive plant, which would require at least three coke drawing machines and a spare one, or four in all, to insure continuous operation.

CONVEYOR FOR RECTANGULAR OVENS.

To receive the coke from the ovens, as pushed out, either a conveyor may be used of the apron type, or a chute as shown.

The chute is much less expensive both in first cost and in maintenance, but it involves more work on the part of the pusher.

Using the chute, there is always an ovenful of coke on the same, the coke from the next oven pushed pushing it on into the car.



No. 23. Self-Propelled Loading and Screening Chute for Long Ovens. Original design by the writer.

LEVELER FOR RECTANGULAR OVENS.

The machine for leveling the coal consists of a structural framework, traveling on the pusher track and carrying a leveler bar, composed of two channels having cross pieces between them like the rungs of a ladder.

This apparatus is adjustable vertically by power.

In the design shown a separate small motor is employed for adjustment which is entirely independent of the main driving motor.

By this means the leveling device may be raised or lowered on either stroke at any time.

QUENCHER FOR RECTANGULAR OVENS.

The quencher is very similar in appearance to the leveler. It carries a reciprocating member upon which is mounted a spray pipe, having small holes in its lower side and extending across the oven.

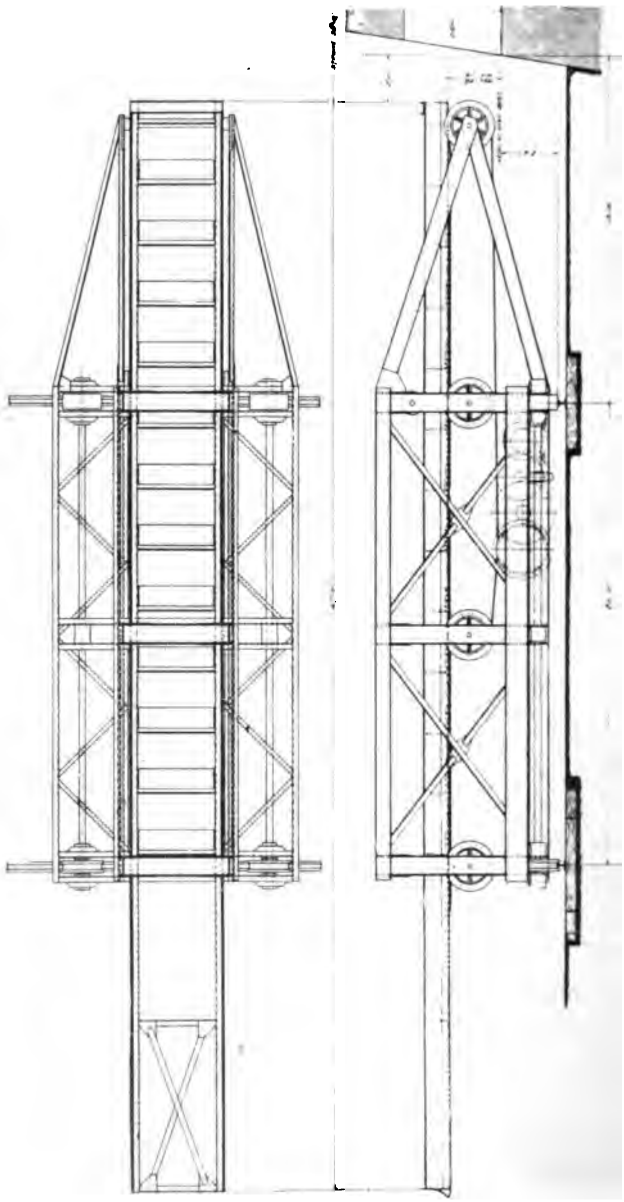
The water supply is delivered to the spray pipe from a stationary connection at the rear of the machine, through a telescopic connection, one pipe within another.

From the stationary rear end, fixed piping extends to the front of the machine, where connection is made with the water plugs in front of ovens, by a hose of such length that several ovens may be watered from the same plug. The several motions of the machine are obtained from a single motor.

The water plugs may be located at the rear of machine.

COMBINED MACHINES.

For small plants where the full capacity of the machinery is not required to produce the day's output, certain combinations of the machines can be made to reduce the cost of installation. For instance, the quencher can be conveniently combined with the pusher and the oven can be pushed as soon as it is watered, without movement of the machine on the track. For large plants requiring the full capacity of the pusher there



No. 26. Leveling Machine for Long Ovens. Original design by the writer.

will probably be required two levelers and two quenchers to each pusher.

GENERAL ADVANTAGES FROM THE USE OF MACHINES.

By the substitution of machines for hand labor in most manufacturing processes, the usual result is a greatly increased production. In many cases results are obtained not possible to be secured by hand labor.

In the use of the machinery above described, these results do not obtain, because the amount of production depends on the ovens.

There are, however, many advantages which may be summarized as follows:

(For the coke drawing machine with hand watering.)

First—A direct saving of 50c per oven, or over, in drawing.

Second—The machines operate independent of weather conditions.

Third—Reduction in the number of laborers at the plant, fewer men to deal with, and of a higher average intelligence.

Fourth—Greater uniformity of product.

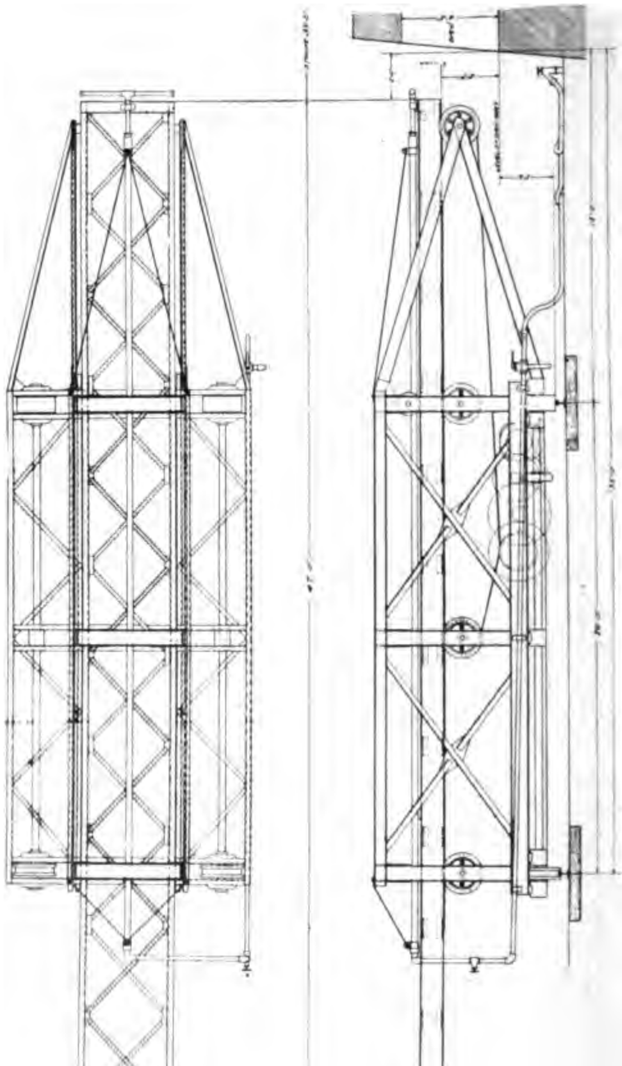
Fifth—More uniform operation of the plant.

Sixth—Saving in time, or usually an increase of output by the utilization of the time saved.

[2]Seventh—"The ovens are watered in advance of the machine by men who do nothing else and who, therefore, can be trained to use only sufficient water to accomplish the desired result. They do not have to consider the heat, which the hand drawer must face; and the foreman can accurately gauge and determine the amount of spraying which they shall do in order to use the minimum amount of water required to deaden the coke."

"Excessive watering occasions a loss of heat and produces black ends; and use of the machine should, in this respect, produce much better results than can be obtained by

[2] From paper by Geo. T. Wickes, read before the A. I. M. I., 1905.



No. 27. Long Oven Quenching Machine. Original design by the writer.

hand drawing, in which many men are employed to water the coke."

[2]Eighth—"After the machine has extracted the coke, if the ovens are immediately recharged, the promptness with which ignition takes place is apparent to even the casual observer and is in strong contrast to the action of ovens which have been drawn by hand and exposed for two or three hours to the cooling action of the air."

Ninth—Machine handles any depth of charge. When machine watering is used, the coke is watered still more uniformly and in less time, involving less loss of heat.

When machine leveling is used, the coal is in better average shape to burn, and the ovens should produce a greater average yield.

DISCUSSION.

Chairman Ely: Now that the question is open for discussion, I would like to ask a question. I noticed that Mr. Macfarren said that a machine which drew coke from the top of the oven was necessarily more expensive than one which hogged it out from the bottom. I cannot see just why that should be, and I would like to hear a little more particularly.

Mr. Macfarren: I criticised the Alliance machine as it was built at the Continental plant, and the Hebb machine. The Hebb machine as originally constructed was a failure. A part of the reason for that may have been due to inferior construction. But as against the inferior construction, they probably put a great deal of enthusiasm into trying to make it work. The new Hebb machine being built for Jones & Laughlin will probably be much better built. But my idea of the over-drawing machines is that they will never be able to compete in speed with the under-drawing machines. You will easily understand that in a machine like the Covington or the Marmac, in which there is a ram, with a wedge-shaped shovel, sliding on the bottom of the oven, the operator has only two

[2] From paper by Geo. T. Wickes, read before the A. I. M. I., 1905.

things to watch. One is the alignment of his ram and the other is the direction and speed at which it is traveling. With the Covington machine the operator controls the alignment by a wheel and screw. He really has to watch only a controller handle which actuates the ram. The ram is actuated by a reversing motor. The travel into the oven is a stroke of about about 16 ft. and out of the oven about the same amount. All he has to look after is that he does not run his ram against the back of the oven, or too far out against the machine. The same is true of any other machine built on these principles. Whereas in any machine acting over the coke, the operator has a good many other things to look after. He has to look out for the stroke of his ram, the level of it, the position of his scraper head and the alignment of it; four or five things as against one or two in the other machine. A machine such as the Hebb machine can draw coke which is larger and deposit it in the car in larger pieces than the under-drawing machine, which necessarily smashes up the coke somewhat. Yet it can never compete commercially, in my opinion, because it will never make any speed. A man can do this work, and while there are not any more men than are required, yet they are still to be had, and in order to save anything the coke drawing machine has to do the work considerably faster than a man, because you do not have any fixed charges, repairs and maintenance to keep up on the man. So that it is a question of speed.

A. Stucki: If I understand matters right the coke is drawn and loaded very quickly, and it looks to me as if it may very often get into the car in a very hot state. In this case the steel coke cars must have a decided advantage over the wooden ones.

Mr. Macfarren says that the cost of leveling the coal by hand is something like 12½c per oven. If there is no other advantage in machine leveling than a certain reduction in cost, the quality and quantity of coke being the same in both cases, it seems that the profit cannot be very great in doing that work by expensive machinery.

I also suppose that this machine has been patented in its principal construction, while the details undoubtedly can be worked out in many different ways, being simply a matter of engineering skill.

Mr. Macfarren: With reference to the point about the coke reaching the car hot, it is watered previous to being drawn and if it is properly watered it will not ignite again. However, I have seen coke going up in a Marmac conveyor which was in flames. It is usual to water the coke again with wooden cars. The great majority of the cars in which coke is shipped are wooden cars. With reference to the question of saving, Mr. Stucki is confusing the price of coke drawing machines, and the investment therein, with the price for leveling. The figure given, 12½c, is the scale price for leveling the coal in the oven and it is not probable that a great deal of money could be saved on the leveling. Mr. Lynch's statement of the case was that with the kind of labor that he had, it was impossible to get good leveling done. The coal would be six inches or eight inches out of level in different parts of the oven. The saving on the coke drawing machine is upwards of 50c per oven.

The Chairman: If most of the ovens, as we understand, are going to be made by-product ovens, will there be much demand for coke drawing machinery in ordinary ovens?

Mr. Macfarren: This long oven they are experimenting with now is not a by-product oven. There is nobody in the Connellsville district that I know of now interested in erecting by-product ovens. The coal is too cheap. I think it is worth about $2,000 an acre, but that only figures fifteen or twenty cents a ton in the ground. These long ovens are of a form adapted to save labor in drawing coke out of the oven, and in leveling and watering. They are built with the idea of saving labor, not of saving by-products. The ovens built for the Connellsville Central Coke Co. have been in operation just a couple of weeks and are entirely satisfactory so far. The pusher pushes out an oven in fifteen seconds. The leveler levels it as level as the top of a board table, five feet by thirty

feet, in from six to eight minutes, and the speed will be increased as the operators become more familiar with the work. The slowest operation at the present time is quenching the oven, and they do this in from ten to fourteen minutes. It takes a certain time for the water to soak into the coke. You cannot put it in at more than a certain speed.

It looks to me as if the more of these long ovens there are in the district the better chance the coke drawing machine man will have to sell to the ovens already existing, because the long ovens will have a great advantage in labor costs.

The Chairman: I suppose from a practical point of view that is right. But it seems to me that in time you are liable to have a good many by-product ovens in the country, and it seems right that if all the gas that is going to waste now could be utilized, it should be done.

Mr. Macfarren: With reference to the point Mr .Ely makes about saving the gases, they are using the gases at some plants now to heat their boilers. Mr. Abraham, formerly superintendent of the Continental plant of the Frick Coke Co., is here tonight and he is conversant with this. Also possibly he will make some remarks about the Covington machines.

E. H. Abraham (Non-Member): So far as utilizing the gas from the ovens is concerned, the Continental No. 1 works of the Frick Coke Co., was the first to install that in this country. They have 40 ovens and it furnishes 950 H. P., being sufficient for the entire operation of their plant, hoisting, making electricity to run the coke machines, the pumps, etc. Since that was installed and since it has proven so successful, they are installing it at many other plants. At the United, and that plant in Westmoreland County beyond Greensburg, they have it now in operation. They are putting ovens on the heat, too, in other plants in Westmoreland. They have lately finished a plant at York's Run, seven miles beyond Uniontown, where they have 100 ovens on the flue with 250 ft. stacks to draw. They have their power plant located directly in the middle and their boiler plants are an equal distance

from each end, leaving 25 ovens that they draw in each direction to the stack. They are producing steam enough there to make power for Fairchance, Kyle, Wynn, Smily and the new Collier plant, as well as the York Run plant. They make the electricity there with the heat from the 100 ovens and operate all those adjoining plants with that power. Washington Run Coal & Coke Co. installed the heat flue to about 80 of their ovens and they are making all the power necessary to operate their entire plant. At the Continental No. 1, which was the pioneer plant, they have never used any coal, excepting under one boiler that they keep in case of an accident. We did not know for a good while how long the flues might last or when they might fail, fall in and cut off the supply, and we kept one boiler ready for emergencies; but we find there seems to be no limit to the length of time the thing will last. They had a little trouble there, but that was on account of the quality of the brick more than anything else. And at York's Run where they are producing the steam for all the other plants making the power, the only trouble they have ever had was that they had too much heat. The idea is this: The flue that leads from the oven, 14 in. in diameter, leads to the main flue that runs parallel to the ovens, which is about 6 ft. 10 in. in diameter. There is a damper in this (14 in.) flue, so that the oven can be shut off when they are watering, and it is removed when the oven has been charged and ready to burn. That allows the heat to pass into the flue. The trunnel head[3] is then closed and sealed perfectly tight and the draft goes in at the door just as in any bee hive oven, but instead of burning out at the trunnel head it burns through this flue. Now, it is a fact that when those ovens are burning and they are producing too much heat, to remove the trunnel head from any number of them injures the coke. In other words, you are burning it exactly as if you were burning an oven with a hole in the crown, and if you have ever been around coke ovens you will know that if there is a small hole in the crown of the oven you

[3] The circular opening, so called, in the top of the bee-hive oven. See Proceedings, 1906, p. 332.

will never make nice bright coke until it is closed up. And that has been the drawback at the York's Run plant. To shut an oven off from the flue by dropping the damper the heat becomes so intense in there that it either warps the damper out of shape or places the oven out of commission in a short time so far as it is concerned connected with the flue. To overcome that they took one of their boilers off and closed down and sealed up the same part of the flue. Later on since they have got on all their power plant I understand they have it pretty well regulated and are no longer bothered with too much heat, or not to any great extent. Possibly during Sundays after a 72-hour charge they still have a heat trouble. At Washington Run plant the superintendent told me that they had the Sterling boilers and in case of an accident all that is necessary is to close the dampers and put it on coal fuel, and he told me that in four months, to the best of his knowledge, there never had been a shovelful of coal put in. It results in a saving in a 100-oven plant of about $11.50 a day, and at larger plants or where they are using more steam for pumping or anything of that kind, the saving is correspondingly greater.

The Chairman: I have heard that by-product oven coke is a good deal softer and does not stand in the blast furnace as well as ordinary coke. Does anybody know anything about it?

Mr. Abraham: We have close to Uniontown 120 by-product ovens and I have seen them in operation time and again, and I am told by the superintendent of the Dunbar furnace that they are making coke there now just as good as the Connellsville coke from the bee-hive oven. In appearance that is not so. It comes out in cubes. In a bee-hive oven the coldest place is the bottom of the oven and there is where you have what is known as the black butts. Good coke depends on how close you can burn it to the entire bottom. If you are overcharged you will have a little coal in the bottom, or for a distance of three or four inches up the coke will be very dark. The blacker the coke is the softer it is supposed to be. In a by-product oven the butts are exactly in the centre. Like

making ice the middle of the cake is the last frozen. If the bottom has burned off perfectly there will be a small black streak right through the centre of the coke and it breaks apart and that is why the coke is so short. The ovens are so narrow and the break-off is in the middle. It separates right in the centre and they don't make anything more than 5 or 6 inches long. And the coke is for other reasons darker than the bee-hive oven coke. In the first place, it is watered outside of the oven. If you draw coke from a bee-hive oven and water it outside, you darken the coke. The colors of the rainbow will show all over that coke. It spoils the appearance of the coke entirely. They have to water it outside in a by-product oven. Whether it is softer than the coke in a bee-hive oven is a question. I do not believe it is, especially if it is well burned off. However, if it is not well burned off and there is some coal through the centre, then the whole mass seems to be very much softer, just as it would be with a bee-hive oven if not properly burned off.

Jacques Negru: I would like to ask Mr. Abraham about those black spots of partly burned coal in the centre of the coke in by-product ovens. This surely indicates that the charge was not homogenous and the heating not uniform, so that the centre remains incompletely coked. I visited many coke oven plants in Belgium and Germany and I have always seen that the cake of coke after being pushed out of the oven and broken by the watering, was as uniform in color as could be. The main care of the coke burner being to have the charge not only level but as homogenous as possible, and then in addition to see that it is uniformly heated. It is easy to see why in a copper, or asphalt, or by-product oven, the charge being a loaf of granulated coal and heated from bottom, top and sides, they get uniform coke. Each oven is a sort of muffle by itself, heated by the gases from the ovens. The width of the ovens being from 50 to 60 cm. (about 2 ft.), the heat always passes through and through in all directions.

Mr. Abraham: I think myself it is possible to burn it almost entirely off. But just as you see in your bee-hive oven,

no matter how well it is burned off, there is the least little scum of black on the bottom, even if you burn a 48-hour charge for 72 hours.

I have often noticed through the centre of the oven, as Mr. Negru says, that the heat is all around it and it burns from every direction, and in a bee-hive oven the burning is from the top and front and never from the bottom. But I always see these little black butts in the by-product oven at the centre, whereas, if it is properly burned, they are lessened a great deal, and there is a great deal in doing it exactly right and not overcharging. In their earnestness to get out a big product from a by-product oven, they are just as liable to overcharge it as we are in a bee-hive oven.

[For further information in regard to quality of coke from bee-hive and by-product ovens, see discussion in Proceedings, present volume, p. 237 f.]

Before Structural Section, September 3d, 1907.

Vice Chairman E. W. Pittman

In the Chair.

Water-Proof Cellar Construction.

BY COLBERT A. MacCLURE, S. B.*

Non-Member.

By "water-proof" let us understand "impervious to water."

The writer knows of no cellar of any considerable size and depth subject to intermittent or constant hydraulic head which, accurately speaking, is water-proof. That such a foundation can be built, there is no doubt.

The term "water-proof cellar" is perhaps most commonly used to express that degree of imperviousness to water which renders the cellar suitable for the purpose for which it is intended. The term will be used in this sense in this paper.

The water-proofing of a stable surface under small hydrostatic head is obviously simple. The problem, however, becomes more serious when it is stated.

Given: A cellar constructed of the usual materials to properly perform its usual functions and in addition, make it water-proof. This immediately brings up for consideration:

First. The flow of water through the earth (excepting where the foundations are built in a body of water),

Second. The hydrostatic pressure due to the water after it has percolated through the earth to contact with the walls and floor of the cellar; and

Third. The best kind of water-proof construction to be adopted under the then existing conditions.

A diligent search of the works on this subject and inquiries made of competent engineers engaged in this kind of

* Of MacClure & Spahr, Architects, Keystone Building, Pittsburgh.

work have not brought forth sufficient data from which to draw conclusions of value. It would seem that the structure of the earth surrounding a cellar to be water-proofed should be definitely and accurately known, as well as the rate of flow through the same, in order to scientifically and correctly solve each problem.

The difficulties attending the gathering of such data are obvious and great. It is, nevertheless, a line of investigation which should be carried on in an exhaustive manner by competent men.

Meanwhile we are all called upon, or may be at any time. to solve a water-proofing problem. To do this certain assumptions must be made.

FLOW OF WATER THROUGH SOILS.

With reference to the flow of water through the soils the writer assumes (1) that the various soils retard the flow of water in various degrees, and (2) that when the water reaches the water-proofed cellar it exerts a pressure thereon due to a hydrostatic head of the level at which the water comes to rest, excepting under conditions hereinafter noted. (3) In absence of adequate data with reference to the rate of flow of water through the various strata of earth, judgment based upon experience is relied upon entirely.

The following data were gathered by Mr. Mulhattan, of Edeburn, Cooper & Co., and the writer during the building of the Union National Bank building, at the corner of Wood Street and Fourth Avenue, city.

The bed of the Monongahela River directly opposite Market Street was the 0 of datum for levels used in the construction of the building.

The finished sub-basement floor is at elevation +6.5.

The elevation of the curb at the corner of the streets above mentioned is 39.82.

The earth was excavated for the principal footings to a depth of 40′-0″ below the curb level of 39.82, which depth is stantially the 0 of the datum used.

Levels were taken of the water in the excavation and it was ascertained that the water level in the Monongahela River and in the excavation were identical in the gravel stratum.

During the excavation for the Diamond National Bank building the water rose but once high enough to enter the hole and its level therein was substantially the same as in the Allegheny River, from which it is two blocks distant. The footings rest on the gravel stratum.

The exact height of the Allegheny River can be measured in the sump well under the floor of the Joseph Horne Company's building when it rises to a point above the bottom of the same. This measurement must, of course, be taken before the sump pumps are started. The footings rest on the gravel stratum.

The Superintendent of Construction of the Farmers National Bank building, at the corner of Fifth Avenue and Wood Street, City, informed the writer that the same condition obtained in the excavation for that building, and that the footings rested on gravel.

A superintendent of a manufacturing plant informed the writer that the water level in the river during the flood of March 15th, 1907, could accurately be measured in a well sunken 300 yards from the bank of the river and that the stratum between the bank and the well was gravel.

From the above it would seem that the flow of water through the strata of gravel in the instances and for the distances mentioned is not materially retarded.

UNION NATIONAL BANK.

Referring now to a drawing of a section taken through the foundations and curb wall of the Union National Bank building, kindly note the diagramitcal illustration, on the left side of the drawing, of the soils found in that place. As a matter of fact, there was no line of demarkation between the sand and the gravel. The sand was fine and mixed with loam at the top of this stratum and became coarser as the ex-

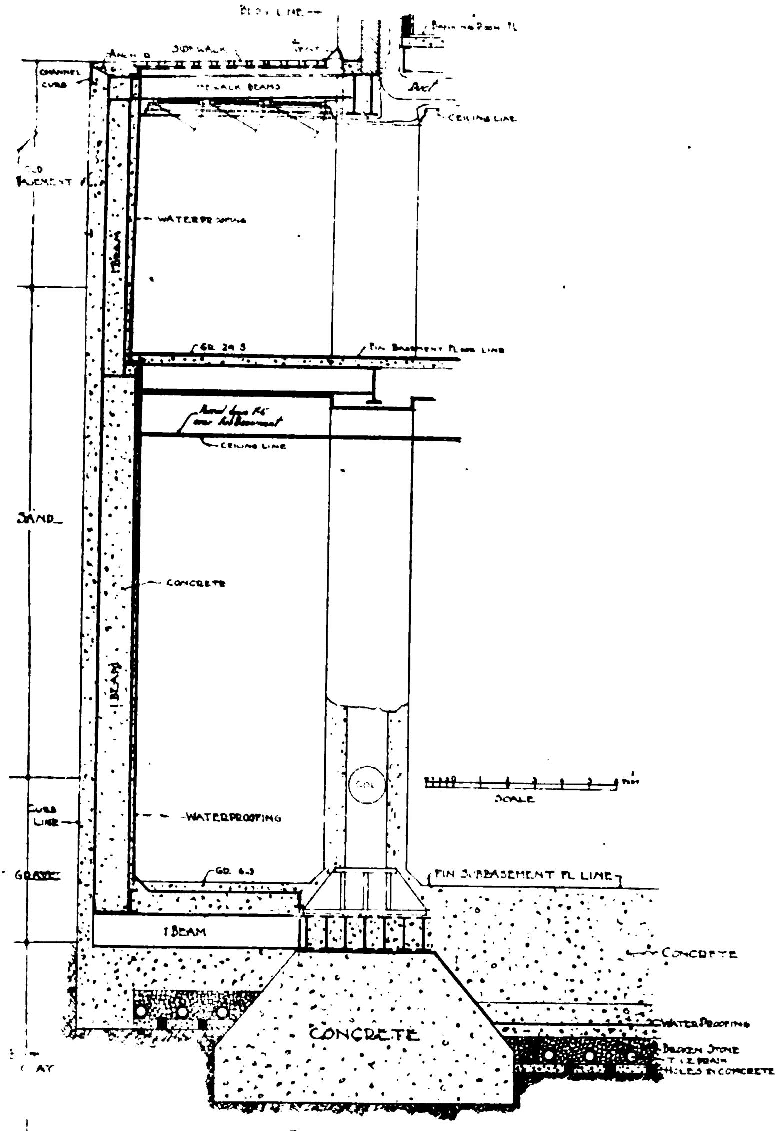


FIG. 1. SECTION-THRO-FOUNDATION
BUILDING FOR THE UNION NAT'L BANK
MacClure & Spahr Archts Pittsburgh-Pa

cavation descended and finally merged into the gravel stratum.

Underneath the gravel kindly note the stratum of blue clay, the top of which is about five feet above the bottom of the footing course. It is a very stiff blue clay. Upon this the building rests.

The construction is that shown on the sectional drawing above mentioned. Kindly note the floor is made of concrete reinforced with steel sections and that it contains a stratum of broken stone in the bottom of which are placed horizontal lines of tile drains. These drains all lead to a sump well, which is emptied by means of two pumps, each having a capacity of 300,000 gallons per day. The water enters the stratum of broken stone through the lowest layer of concrete, which is pierced two feet on centers both ways by 6-inch tile set vertically. The selection of the size of pumps was purely a matter of judgment. The assumption made with reference to the amount of water which would percolate through the clay stratum and which in this form of construction should be pumped, was that the clay, upon which the building rested, owing to its peculiar character, would act somewhat after the manner of a gasket; that the water would freely percolate through the strata of sand and gravel and that, in consequence, the full hydrostatic head would be exerted against the outer rim of the foundation above the clay. During the flood of March 15th, 1907, the water rose to within two and a half feet of the curb elevation at the corner of Fourth Avenue and Wood Street. There was but a short time during the period of this flood when one pump alone could not have discharged the water which flowed into the sump well.

Unfortunately no gauges were installed at the time of this flood and there is no way of knowing the exact pressure exerted against the various portions of the basement. There were no leaks discovered anywhere in the floor during the flood above mentioned, but there were leaks at the basement floor level where the beams of said floor pierced the water-proofing of the curb walls. This will be discussed later in connection with water-proof coatings.

From the force with which the water came through these leaks there can be no doubt but that there was considerable pressure back of the same and it should be noted that these beams pierced the water-proof coating on the walls at about twenty-two feet above the level of the water-proof coating in the sub-basement floor construction.

During a rise in the river prior to the flood of March 15th, and after a portion of the water-proofing had been put on the lower part of the walls, a leak occurred. Upon investigation it was discovered that the foot of a rubber boot had been dumped into the concrete during the construction of the wall, which had so weakened it as to cause the wall to give way at that point and thus break the water-proof coating. This leak occurred about four feet from the sub-basement floor. While the water was around the building the wall was opened up and a stream of water about the size of a man's wrist came through the wall with such force as to strike the floor several feet from the wall.

Following the assumption made with reference to the amount of water which would percolate through the stratum of clay, the sub-basement floor construction was made of such strength that if the pumps should fail absolutely and the pressure could not be relieved, the floor would be strong enough to withstand the pressure and a factor of safety of but two was allowed under these conditions.

Referring now to drawing (Fig. 2), which is a section through the basement of the Diamond National Bank building, you will note that a similar form of construction of the sub-basement floor has been adopted. In this case, however, there is no sump well and no provisions are made to relieve the pressure on either the walls or the floor. The entire floor and wall construction is made of sufficient strength to withstand the full hydrostatic head which would be due to the high-water mark of 1885, namely, elevation 35. and a factor of safety of four was allowed. This happens to be the elevation of the curb around this building at its lowest point. The flood of March 15th, 1907, which has been estimated to have risen to

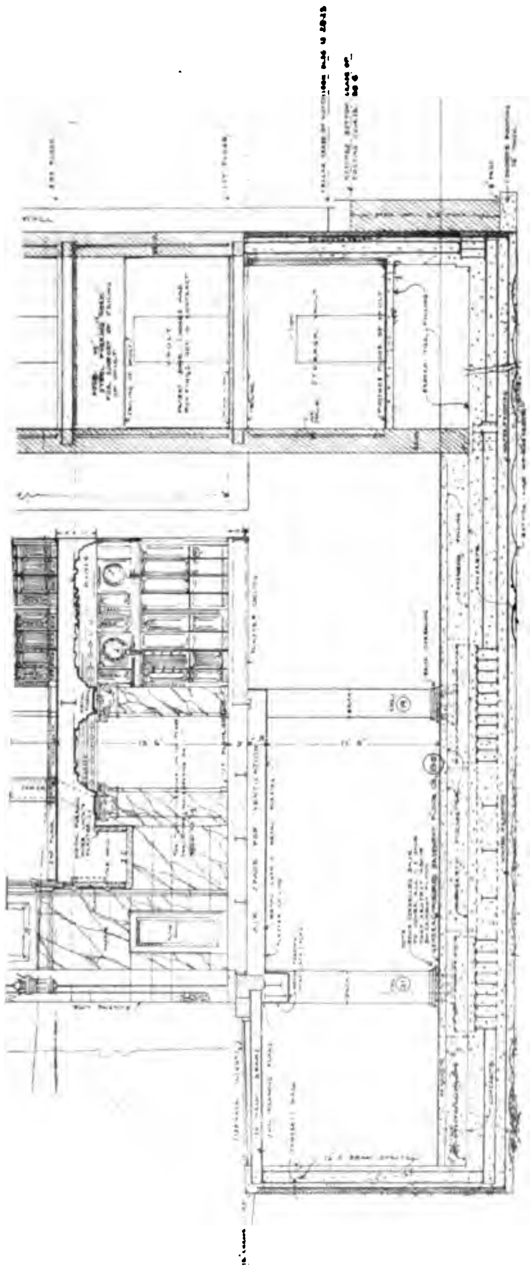


FIG. 2.

Arches similar to these over the entire area of the basement, excepting under grillage, beams or columns.

the level of 36.60, was, therefore, higher than the building was designed to withstand. There were, by reason of this fact, three or four leaks above the height of the water-proofing course and there were two leaks below this level. All the water that came into the building was pumped out by the use of one 4x6-inch house pump.

Neglecting the live load in the building, the estimated uplift due to the flood of March 15th, 1907, was but about thirty tons less than the dead load of the building. The friction of the earth against the foundation walls should, of course, be taken into account.

Since the writer's experience has been limited to but two systems of water-proofing, namely: what is known as the "tar and felt" and the "hydrolithic" cement, only these will be considered in this paper.

The drawings of the Union National and the Diamond National Bank buildings are exhibited here because each is an example of one of these systems. In both systems the walls and floors to be water-proofed must be of sufficient strength to resist the hydrostatic head, because neither water-proofing stratum possesses this virtue.

TAR AND FELT SYSTEM.

Under the term "tar and felt" system are included these systems which use paper or felt as a vehicle for liquid tar, asphalt, "Hydrex," etc., or a combination of two or more of the same. So far as the writer knows they are all applied alike and as follows:

The concrete, which is to receive the water-proof coating. should be carefully troweled smooth before the first layer of felt is applied. All these surfaces should be perfectly dry. On the surfaces thus prepared sheets of paper, or felt, are laid. On the first sheet a layer of the hot compound is applied and then another sheet of felt and then another layer of compound and so on until there are three to five, or more, layers in place. The felt is laid with lap joints, making a full lap of about thirty inches on the sides and a lap of about twelve inches at

the end of each row. On top, or inside, of this is placed the construction which is to resist the pressure. The water-proofing qualities of this system depend upon each layers being quickly and uniformly and thoroughly pressed into the compound, which is usually kept at as high a temperature as is practicable. The joints around pipes, etc., piercing this water-proofing are usually made with flanges, by means of which pressure can be exerted on the water-proof coating to hold it in place.

By referring to the drawing of the Diamond National Bank building you will note that this water-proof coating occurs on top of the lowest stratum of concrete forming the floor and on the *outside* of the curb walls and on the owner's side of the neighbor's wall. A course of bricks or blocks is put on the outside of the water-proofiing against the curb wall to protect the coating from being pierced by the filling in of the earth around the same. A wall is built inside of the water-proof coating against the neighbor's building and made of sufficient strength to resist the pressure. This coating extends underneath the grillage and all the steel members are protected thereby from water. The lowest stratum of concrete is arched, excepting where it occurs under the footings, and the centers are withdrawn. This is done in order that when the building settles the reinforced concrete floor between the footings shall not take the load which it was not designed to sustain. On account of this settlement it is good practice to substitute underneath the grillage beams sheets of soft copper for the water-proofing course, in order that there may be an expansion joint made between the copper and the layers of felt or paper, thus preventing the breaking of the water-proofing course when the building settles. Since the water-proof coating should be put underneath the grillage, it is evident that the columns on top of said grillage will not be fully loaded until some months later and except in the case of rock foundation there is sure to be more or less settlement.

The water-proof course must be placed *outside* of the vertical wall and on the underside of the basement floor for the

reason that it has not adhesive qualities sufficient to resist the hydrostatic pressure. In consequence, if a leak occurs in the floor, and, as stated above, the writer has never known of a water-proofing job of any considerable size in which a leak has not occurred, it is obviously necessary to dig through the mass of concrete to repair it. Leaks, in this form of construction, may manifest themselves twenty or more feet from their actual location, because the water, upon entering a mass of concrete, naturally follows the line of least resistance which, in all human probability, will not occur in the concrete vertically over the rupture in the water-proof coating. If a leak occurs in the curb walls it is necessary to excavate outside said walls to repair it. The success of this system depends, to an enormous extent, upon the carefulness of the workman laying the felt and the care of the same until permanently protected.

HYDROLITHIC CEMENT.

Hydrolithic cement resembles ordinary cement very closely in regard to weight, strength, color and other physical properties. One striking difference is that it will not readily absorb a drop of water put into it, and in this particular is readily distinguishable from the ordinary cement.

It is mixed with sand in the proportions of one to two and after the walls have been thoroughly chipped and cleaned it is applied upon the same in two coats aggregating five-eighths of an inch in thickness.

When used for the water-proofing of floors it is placed upon the upper surface of the concrete slab in one coat, usually one inch in thickness, and troweled to a smooth surface, which, in seven days, becomes sufficiently hard to be used as a finished floor. As in the case of the walls, the concrete floor slab is thoroughly chipped and cleaned before the coating is applied. The only difference between the ingredients for the floor and the wall coating is, that for the floors coarser sand is used, producing a surface resembling the granolithic floor finish.

This coating can be placed on the walls while water stands behind the same and also can be put onto the walls successfully through which water is not only seeping but streaming. This is done by a system of porcelain tubes, which has been patented by the inventor of the cement, Mr. E. J. Winslow.

For floor work, however, it is necessary to relieve the pressure until the cement has become firmly set, and for this purpose a system of sub-drainage is usually placed, such as is shown on the sectional drawing of the Union National Bank building.

Where it is not intended to use the sump and drainage system in connection with the water-proofing, the company applying this material install a steel sump varying in diameter from 6 in. to 12 in. and running in length from 2½ ft. to 7 or 8 ft. The lower end of this steel sump is perforated, which allows the water to freely enter the same. It is equipped with a cap which is screwed tightly into place as soon as the pumping is stopped. These steel sumps are left in place and in case of leaks occurring the pump can again be applied while the repair is being made. Where the water proofing also serves as a finished floor it is liable to damage by abrasion and the dropping of heavy pieces of machinery upon it.

The surfaces upon which this coating is placed must not only be strong enough to withstand the water pressure, but must, in addition, be of such a character as not to crack either from expansion or contraction or undue settlement. To this end it is essential that concrete walls and floors be reinforced against shrinkage. This can be done at a small expense by placing reinforced rods in the slabs where structural members do not occur.

FORMULA BY MR. MOULTON

Mr. S. A. Moulton, engineer in the office of I. W. Jones, Esq., at Milton, New Hampshire, has kindly given the writer a copy of the formula which he has derived to accomplish this work. From the reports received, it appears that Mr. Moul-

ton has evolved a highly useful formula, not only in connection with water-proofing, but also in connection with concrete construction, such as retaining walls, etc. The writer wishes here to ascribe this formula to Mr. Moulton and to thank him for the use thereof.

The writer is informed that the walls of a very large paper mill near Portland, Me., were reinforced in accordance with this formula and that they have withstood successfully the expansion and contraction during the past three years under a temperature varying from —20 to +80° Fahrenheit, without showing signs of expansion and contraction cracks. This formula calls for a mixture of 1—2½—5 of concrete and solves as follows:

For a slab of 6″ in thickness .333 sq. in. of steel per square foot of surface is required.

For a slab 8″ in thickness .444 sq. in. of steel per square foot of surface is required.

For a slab 10″ in thickness .555 sq. in. of steel per square foot of surface is required.

For a slab 12″ in thickness .666 sq. in. of steel per square foot of surface is required. And so on in the same ratio.

It will be noted that the number of square inches of steel for the respective thicknesses of slab may be obtained by dividing the thickness of the slab by two and reading three of the digits thus obtained with the decimal point in front of the same.

The formula is as follows:

w = Area of metal in square inches.
t = Tensile strength of concrete per square inch, [ultimate].
d = Thickness of slab, or wall, in inches.
b = Breadth, or width, of cross section in inches.
s = Total stress in pounds.
El = Elastic limit of steel.
A = Area of cross section in square inches.
ψ = Constant for $\frac{\text{Area metal in square inches.}}{\text{Area of cross section.}}$

GENERAL FORMULAS.

No. 1. $d\,b\,t = s$

No. 2. $\frac{5}{.95El} = w$

No. 3. $A = d\,b$.

No. 4. $\psi = \frac{w}{A}$

No. 5. $w = \frac{d\,b\,t}{.95El}$

No. 6. $\psi = \frac{w}{d\,b}$

No. 7. $\psi = \frac{t}{.95El}$

No. 8. $w = \frac{t\,A}{.95El}$

No. 9. $w = \psi\,A$

Applying No. 8: $t = 220$ pounds for 1——2½——5 concrete using steel with $El = 50{,}000$ pounds, (owing to variations in area of metal and also of El it is advisable to reduce El by 5% as given in No. 2). Taking a floor slab 10 inches thick and a section of the same 12 inches wide, No. 3 will be $10 \times 12 = 120$ square inches, and No. 8 $\frac{220 \times 20}{.95 \times 50{,}000}$ $= .555$ square inches of metal required. Hence, for 1——2½——5 concrete No. 4 $\psi = \frac{.555}{120}$ or 0.004625 and for 1——2——4 concrete with $t = 250$, $\psi = 0.00525$. It is evident that the constant ψ only applies when metal of the same El is used, but new constants can be obtained by multiplying ψ by $\frac{El \text{ given.}}{El \text{ required.}}$

In placing the steel it is advisable to use a large number of small rods in preference to a small number of large rods, and for walls exposed on both sides the material should be uniformly distributed throughout the slab. If, however, the wall is low and long, it is better to have the majority of the rods running lengthwise. If the wall is as long as it is high, then the rods should be placed evenly, the number of vertical rods being equal to the horizontal ones.

For floor slabs resting immediately on soil some authorities on reinforcing maintain that there is no necessity for placing any steel in the lower half of the slab. Frederick S. Greene, Esq., water-proofing engineer of New York, has informed the writer that his experience leads him to conclude this assump-

tion to be correct. Drawing (Fig. 3) shows a floor reinforced in accordance with this formula.

By placing the reinforced material in concrete it can be readily determined just how much the concrete is strengthened and it will be found that the walls can be considerably reduced in thickness by the addition of this reinforcing, so that the cost of such a wall will exceed but little, if any, the cost of a wall to do the same work which is not so reinforced.

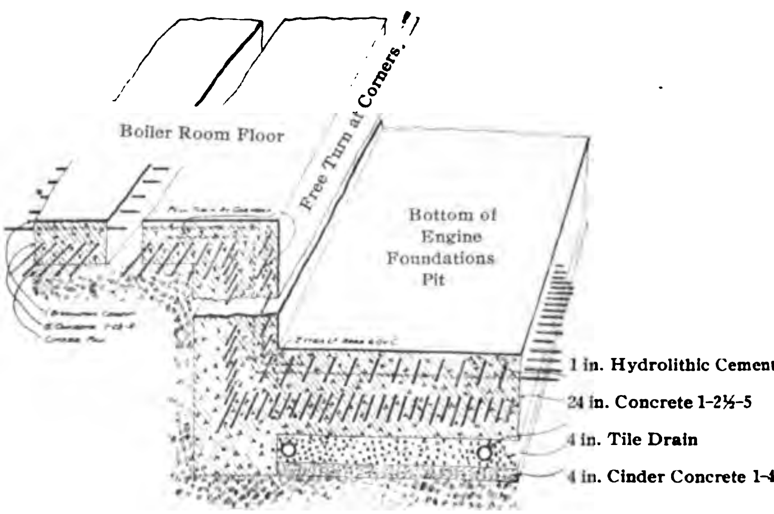


FIG. 3.

This coating cannot successfully be used as a grout and water-proof coating at the same time, because, to be efficient, it must be thoroughly and carefully troweled. For this reason all points which are to be protected by it should be accessible to the workmen.

Where machinery foundations occur in the floor construction a hole is left in the rough concrete, of proper size and shape, to receive the same and the water-proofing is carried down the sides and across the bottom and carefully joined to the horizontal stratum at the higher level. Since a leak under a foundation would be very difficult to mend the indentation

in the rough concrete is sometimes made about 6 in. wider on all four sides and the concrete forming the foundation of the machinery is cast in a form separately from the general construction and placed on top of the water-proofing. Hand holes are left in this engine foundation so that the bolts on the rods holding the bed plate can be removed and the finished foundation lifted out of the pit. The 6 in. around the engine foundation is usually filled in with terra cotta blocks, which can be readily removed. The finished floor is extended over these blocks.

Hydrolithic cement *can* be bonded to steel or iron in such a manner as to make a water-tight joint. In this case the metal must first be sand blasted. If the pipes or steel members are not subject to a marked change in temperature the coating is brought up to the same and a water-tight joint secured without any additional appliance. Where the steel member, or pipe, is subject to undue expansion and contraction, such as those which carry hot water or steam, it is necessary to fit collars about them against which the coating may be made up to. The joint between the collar and pipe is caulked with lead.

While a bond between this coating and steel, or iron, can be made a perfect joint, it is delicate, since it can be broken by either vibration, expansion or contraction.

In the case of water-proofing under boilers it is necessary to drop the coating beneath the same to a sufficient distance to allow the placing of two layers of fire-brick over it, and in front of the boiler where hot ashes are drawn out, one layer of fire-brick will furnish the required protection.

The leaks above the basement floor beams of the Union National Bank building, where they pierce the water-proofing on the curb walls, are mentioned above. These beams are riveted to a horizontal channel running, as shown on the drawing just mentioned, and the channel is embedded in the constructional concrete of the wall. This is one of the most difficult joints to make and could have been avoided had the difficulty been appreciated. In order to make these joints

tight it was necessary to rivet angles to the sides of the floor beams in order to do the work done by the collar around the pipes above described. It would undoubtedly be better to make a shelf in the wall where beams occur and to permit the water-proof coating to be placed around the ends of the beams before they are put in place.

With reference to the advantages or disadvantages of placing the coating on the interior and exterior surfaces of a basement: Under certain conditions it may be a disadvantage to place the coating on the interior for the reason that the walls and floors are subject to the action of water.

If there are no structural steel members in these floors it would, perhaps, not be a disadvantage if looked at from the point of many authorities on concrete who agree that when it is immersed in water it becomes stronger and harder and less subject to disintegration than if exposed to the air. It also reduces the change in dimensions of a concrete slab by reason of keeping it at a more uniform temperature than if exposed to the air. As the "Hydrolithic" cement is applied to masonry and brick walls as well as to concrete containing steel members, the conditions under which so doing becomes a disadvantage would have to be determined for each problem. This "Hydrolithic" cement has shown by test to have an adhesive force to concrete of 140 pounds per square inch, which is probably sufficient for all ordinary uses in connection with the water-proofing of cellars. The advantages of placing the coating on the inside are as follows:

First. Being thus placed the exact point of the leak is easily located. The crack can be cut out and refilled with new cement and the entire repairs made with but slight expense. This advantage seems to the writer to be one of prime importance and in this particular the "Hydrolithic" cement system is far superior to the "tar and felt" system.

Second. With the "tar and felt" water-proofing system it is always necessary to build a supporting wall for the water-proofing itself, which will vary in thickness according to the depth of the basement and in most cases would probably

be from four to sixteen inches in thickness. In addition the earth must be excavated a sufficient distance outside of the walls to be so treated, to permit the workmen to descend and apply the water-proofing. In city buildings where street car tracks, electric ducts, water pipes, sewers, shoring and various other things are to be contended with, this becomes a serious question.

Third. "Hydrolithic" cement will itself form a finished floor and a presentable finish on the interior of the walls, and in the case of the latter, may be decorated as a plaster wall is decorated.

Fourth. For the same requirements and under the same conditions the thickness of a cellar floor construction can be made less with the "Hydrolithic" cement than with the "tar and felt" system.

Fifth. The "Hydrolithic" cement system can be applied with less inconvenience to the general contractor and will thus expedite the work of building.

The inventor of the "Hydrolithic" cement, Mr. E. J. Winslow, is said to guarantee that there is neither vegetable nor animal matter used in the cement; that it is a mineral throughout and, consequently, not subject to decomposition or disintegration and that, on the other hand, becomes stronger with age.

So far as the writer knows, this system of water-proofing has come into practice within the last few years and, in consequence, the life of the compound has yet to be tested by time. He has, however, not the slightest reason for doubting the statement attributed to Mr. Winslow. In case, however, the water-proofing give way, the fact that it is applied on the inside would make it comparatively easy to replace.

The water-proofing of a cellar which is constantly surrounded by water during its construction is less difficult to make water-tight by the "Hydrolithic" system than when the head is intermittent, because, as the water-proofing is applied there is a constant test upon it, whereas, in the case of intermittent pressure, such as obtains in Pittsburgh, no satisfac-

tory test can be had until the flood comes, and if the water-proofing fails the worst happens. For this reason the greatest care should be exercised, not only in regard to the applying of the water-proof coating, but also in regard to the strength of the walls and floors of the basement to be water-proofed. Just as in the designing of retaining and revetment walls under various conditions, so it is in regard to the designing of water-proof cellars. Owing to the lack of sufficient data, the points upon which the success or failure of the work depends must be largely determined by judgment and experience, under which conditions the most competent and conservative will sometimes seriously err.

The writer wishes to acknowledge his indebtedness to Mr. S. C. Weiskopf, who was consulting structural engineer in regard to the two building herein referred to, and to Mr. Greene, above mentioned, for information used in writing this paper.

DISCUSSION.

L. P. Blum: What is the composition of hydrolithic cement?

Mr. MacClure: It consists of Portland cement of good quality, with sand sometimes, water, and a secret composition which is added during the mixing. This used to be added in liquid form. At present it is being added in a powdered form. It is also being mixed dry with the cement at the factory by machinery and shipped to the sites in barrels. The success of this cement water-proofing depends largely upon the thorough troweling of the same after it is placed in position.

A Member: Why is it that thinner walls can be used with that interior water-proofing than when you put it on the outside?

Mr. MacClure: For two reasons: First, because the wall put outside the tar and felt coating to protect the same, adds little or no strength to the said wall, since it is not bonded to

it; and, second, because the reinforcing to provide against shrinkage also increases the strength of the concrete.

E. A. Godfrey: In the case of the rubber boots concrete, where you made concrete out of rubber boots, why didn't the water proofing stick with a tension of 140 pounds per square inch? That would be sufficient to meet all the head of water, but you said it raised or blistered on the wall.

Mr. MacClure: It did stick to the concrete between the boot and itself, but the water pressure pulled the wall out with it, the part between the rubber boot and the inner surface. There is not a great amount of adhesion between rubber boots and ordinary concrete, so when the water got around that boot and started the piece out, it carried with it the little skin of concrete and the water-proofing.

Mr. Godfrey: If they did not have the rubber boot in the concrete, would it have that blister?

Mr. MacClure: Not if the water-proofing coat had been properly applied. It has been tested up to 140 pounds per square inch for adhesion to concrete.

Mr. Godfrey: I know you said that, but that does not seem to correspond with what you had said previously that it would exhibit itself by blisters, which would look like the cement pulling away.

Mr. MacClure: Suppose, instead of concrete between the curb wall, which has steel beams, we had a piece of rubber stretched, and you could apply this water-proofing coating to the rubber. Manifestly it would not hold, because rubber cannot withstand the hydrostatic pressure, therefore it would bulge in.

Mr. Godfrey: That would be a failure of the wall, not of the coating.

Mr. MacClure: That is exactly what occurred.

Jas. A. McConnell: Isn't the water-proofing a matter of sufficient importance, considering its comparatively small cost and the large cost of the entire building, to justify the using of both systems, placing your tar felt on the outer surface and

the hydrolithic on the inner surface, or first your tar felt, and the hydrolithic could be applied at any time?

Mr. MacClure: That can be done, but if either system is done perfectly you would not need both.

A Member: That brick wall that is put outside of the felt, is that laid up in cement?

Mr. MacClure: Yes. You have your sheet piling there with space enough between the wall and the same for a man to get down and work. If you pull out this shoring and all this gravel and stones went in it would be likely to puncture the felt by the mere force of its falling, or by tamping and this wall is put in simply to keep the earth from puncturing the felt.

Mr. Blum: As I understand it, your idea with an engine foundation, is to put the water-proofing entirely underneath the foundation. Would you consider that good practice with a very large engine? I understand in office buildings you do not have very large engines, but in a manufacturing plant. You put your water-proofing in a place where it is pretty nearly impossible to get at it.

Mr. MacClure: Where would you put it?

Mr. Blum: You speak of the adherence of this hydrolithic cement to ordinary concrete. If in engine foundations the hydrolithic cement layer were put two feet below the top of the concrete, would the jar of the engine be enough to injure it, the hydrolithic layer?

Mr. MacClure: I do not imagine it would if it were put in the construction of the floor proper. But we have found that where you put your various engines on a floor of that construction, which is reinforced by steel rivetted to the grillage, the vibration or telegraphing would run to the grillage, thence to the bed plates and thence to the column and through the building. As a matter of fact, we have always used sand cushions to keep this vibration from telegraphing through the building. The pit in the concrete and the foundation for the engine are cast separately and the space between them is filled in with sand. There used to be a theory

that if the sand got wet it would not be efficient, but we have found that it acts just about as well wet as dry.

The greatest cause of this telegraphing of sound, as far as we have discovered, has been the hanging of the pipes, particularly the high pressure pipes, on the floor beams and girders. Now we always put them on stands and carry them down to the concrete floor. Of course, the engine builder says, "I want such a weight or size or depth of concrete under the engine." We give him exactly what he asks, if our depth of floor will allow it. He wants a certain weight to keep the engine from vibrating. If we cannot give it to him on account of our floors being too thin, we put steel in and make it heavy enough. But we then put our sand around it and about 4 in. boards at the bottom, and he gets what he asks for and gets the results.

Fred C. Schatz: I have tried two ways of water-proofing engine foundations. The best practice I know of is to prepare a good concrete foundation at least two feet in depth to resist the water, and to bury in the top of this concrete a number of pieces of timber about 6x6. After the concrete is set, remove the timber and bond the concrete and brick-work together with cement. Commence the brick-work and anchor bolt washers above the water-resisting concrete foundation, continuing the brick-work and anchor bolt construction in the usual way. By this general construction accomplish the same idea that hydrolithic cement would tend to accomplish if it were put at the bottom of the foundation. While it is generally supposed that anchor bolts can be grouted perfectly tight with cement, my experience proves that it cannot be relied upon.

One engine foundation we built was along these lines. We commenced with about 2 feet of rich concrete, placed a certain amount of timber on the top of same, the timber being about 6x6 inches, which after being removed, formed troughs of concrete. The foundation bolts and brick-work were started from the top of the foundation and bonded together with grouting, the troughs left in the concrete preventing any slip-

page of one part of the foundation from another. This form of construction has proven water-tight and has given us no trouble whatever. In other foundations which we have built, where the anchor bolts were run to practically the bottom of the foundation and dependence was placed upon grouting the anchor bolts with cement and making the same tight, leakage invariably occurred. In this latter instance we took special pains to have each course of brick-work grouted and though the head of water was not over 14 feet at the base, still the leakage was exceedingly annoying. To me the natural thing would be to have the water-proofing course practically independent of the foundation, as far as leakage is concerned, although both be tied together as if one construction.

In 1892 we prepared foundations for engines from which we expected a certain amount of vibration and resorted to sand cushions. At that time the engines were running at 350 revolutions per minute. Most all the piping was anchored or tied to the steel work. We were annoyed to a considerable extent from the telegraphing of sound or vibration. A recent engine which we installed operating about 175 revolutions per minute and resting on a water-proof foundation, such as I have described, causes practically no transmission of vibration or sound, although in this case the piping is suspended from the steel work. No doubt the better practice is to avoid suspending any pipes from steel construction.

Mr. McConnell: There is a minor point, in using a system of felt and asphaltum and the use of the copper sheet, shouldn't that copper project somewhat all the way around this foundation?

Mr. MacClure: Yes, far enough to stick it between the layers of felt and thus secure a bond. I have never seen a successful expansion or settling joint made with a tarred felt, because the tar on the felt is hot when laid and the folds of the felt stick together.

The fact that the water-proofing has to be put in before the column is loaded is a serious proposition. The first section of a column only weighs a few tons and later it receives

its full share of the total load of the building—and, unless on rock, will settle more or less.

Mr. Blum: Your figures with reference to the Diamond National Bank building, show that there was really an excess of only thirty tons in the dead weight of the building over the displacement. That practically means that so far as that dead load is concerned the margin of safety would entirely disappear if the water had risen probably an inch; that after that inch of rise the only thing to hold the building down would be the friction of the walls.

Mr. MacClure: And the live load.

Mr. Blum: Which is not very much.

Mr. MacClure: No, it was not very large. That whole building was designed to provide for a recurrence of the high water of 1884 and no more.

Mr. Blum: The point is that you have practically reached the limit as to the depth of the basement at the Diamond Bank building without resorting to the collection of the water and pumping it. Is that not the truth?

Mr. MacClure: No, there are other means of overcoming the uplift.

Morris Knowles: Is it not true that by pumping the danger is greater than by letting the water come in?

Mr. MacClure: Pumping from underneath the foundation would relieve the pressure.

Mr. Knowles: Are not the sumps above and within the basement floor to take away seepage that comes in and not to relieve pressure?

Mr. MacClure: They are to take away seepage and that relieves pressure.

Mr. Knowles: Then you pump out of a sump below the floor and take all the water that will collect through these tiles? (indicating on drawing).

Mr. MacClure: Exactly.

Mr. Schatz: If I understand Mr. MacClure correctly, he wished to convey the impression that the theoretical load of the building and the uplift of water were so nearly balanced,

that there was only thirty tons difference. That was based upon the supposition that the water-proofing was tight and neglecting the friction of the foundation. The releasing of that uplift of water, either by leakage or otherwise, would change that relation decidedly. I have in mind an installation where preparations had been made for relieving the pressure of the floors because the distance between the columns was 24 feet. The distance between the columns was so great in this case, and as no special preparations had been made for taking care of the heavy uplift, it became necessary to place French drain system and sump pits under these spans to relieve the uplift pressure of the water. The French drain system and sump pit were arranged as follows: Assuming the floor level to be 22.5 feet, the French drain system was placed about 16.5 feet and the sump pit into which flowed the water from the French drain system, was placed at a level of about 10.5 feet, so that the pressure before it tending to lift the floor, found its way into the French drain system and from there in turn to the sump well and from the sump well was ejected from the building.

During the flood of March 15th, 1907, Horne Co. ejected about three million gallons of water in 24 hours.

Mr. MacClure: Take the bleeding system Mr. Winslow has designed where he wishes to repair a crack or where he puts water-proofing in a building already existing. It is surprising how three or four bleeders 1½ inches in diameter will relieve that pressure. Because, excepting in very loose ground, the ordinary soil retards very much the flow of water. When it is drawn out it takes some time for more to come back.

A Member: That is the trouble with London. The drain system of London has greatly reduced the natural water system, so that buildings are settling because the water is gone. And Engineers in England have suggested putting in pipes and pumping water from the Thames to make the ground have its natural water condition.

Mr. Knowles: Occasionally it is not practicable to design a structure such that if it should be entirely water-tight it would stand the uplift of the ground water at an excessively high elevation. It may surprise you to know that at the filtered water reservoir at the filtration works, if the river height should get up to the neighborhod of 40 feet, it would flood the reservoir if it was empty. Naturally we do not try to design the floor strong enough so that if it be water-tight, it will resist the maximum upward pressure of the water.

Mr. MacClure: You saw a picture recently of a brick cistern which had been washed out and was actually floating down the river.

Mr. Knowles: Because we do not want the floor cracked during a flood stage, we will place some brass tables containing a notice of warning, stating that if the river elevation gets above 40 feet not to allow the water in the reservoir to become lower. There is a filter at Lawrence, Mass., which has a relieving pipe coming up through the floor and above the level of the sand.

L. J. Affelder: You say there is no object in having the bottom of the filters water-proof?

Mr. Knowles: The filters are not subject to this danger, being above river level. There is no attempt to water-proof the filtered water reservoir, the concrete floor is 8 inches thick, made of two layers. Any water coming in from the gravel stratum below would be filtered through a longer distance that it has passed in a filter bed to purify it. The water pumped out of the river bed within the coffer dam was excellent water.

Mr. Schatz: I would like to ask Mr. Knowles where he would consider it advisable to place a French drain system in a concrete floor, for instance as in the case of the Diamond National Bank building. Should the French drain system be near the top, midway or at the bottom of the water resisting concrete, or is it advisable to put in any French drain system at all to relieve the uplift due to the water; assuming that the water had to percolate through the gravel from the river for a

distance of at least a square? The question is often asked whether a French drain system should be built entirely independent of the concrete construction (that is entirely in the gravel), or whether it should be built as a part of the concrete construction.

Mr. Knowles: Isn't that what you have here? It is entirely below the concrete floor. I will answer your question by asking another. If you are going to have the water-proofing good, why do you have your sump for the ground water? Why do you puncture your water-proofing at all if your floor is strong enough to take the uplift?

Mr. Schatz: At best, it is a great risk, and the question naturally arises, is it better to pump the water or is it better to separate that expense and responsibility by having a French drain?

Mr. Knowles: It strikes me as a matter of argument that if the water-proofing is as excellent as this seems to be it would not pay to design a building (providing the weight is heavy enough to withstand the uplift) with drains and outside catch-basin, but instead with a sump inside of the water-proofing, and simply take care of the small amount of leakage that may come through. But this problem has been handled from an entirely different point of view. If you are going to have tile drains, etc., there is no advantage in separating the floor, part above and the part below such drains. But if water-proofing continues to be as successful as this apparently is, why have the drains below the floor at all, why not save the money?

Mr. Schatz: If one were to build a floor at the level of 6.5 feet half the year it would be below the level of the Allegheny River and you would have a continuous leakage to contend with if there were any defects. It follows that there should naturally be some provision made for drainage by sump wells or otherwise. That condition you would have to provide for, because there is no question but that it would be quite a risk to assume for half the year.

Mr. Knowles: If water-proofing cannot be successfully done a leakage is possible. Is it not permissible to consider that you will allow a small leakage to run over the surface of the floor in grooves to such drains as you may have, and from those drains collect in your sump a short distance below the floor level, but still above the water-proofing and the pump take it from that?

Mr. Schatz: I don't believe it would be permissible.

Mr. MacClure: That is the reason we put it underneath the floor. When a man designs a water-proof building and puts sumps under it, he simply announces that all human beings err and do not do things theoretically perfect. I shall do the best I can, and I am going to pay an insurance against imperfect labor and materials by buying the drains, sump and pump.

Mr. Knowles: The dampness to which you refer as being objectionable is due to the humidity of the atmosphere. That humidity is just as great due to the dampness of the walls as to running water. Why not have channels in the floor at frequent intervals collecting the water?

Mr. MacClure: We do, but we put them underneath the floor, so we will not have a damp cellar. Walls are not damp if water-prooofed, as has been done several times in this city.

Mr. Schatz: I have in mind a suggestion that an engineer in the local United States Engineer's Office made. He suggested that a concrete floor be built of 18 inches of concrete, small concrete piers placed on this, and another floor placed on the concrete piers, the object being to make the lower portion water-tight and the space between the floors to receive any leakage and from which the leakage could be collected and ejected. He claims that by so doing you can reduce the pumpage and also have a good system of drains beneath the floor. The space between the floors need not be over six inches. He believed that by this method you could reduce the amount of water necessary to be ejected, and that leakage becomes a negligable factor. Also that the dampness can be obviated to some extent. He has never seen it

tried in a building but knows of its use in locks and dams on river work.

Mr. MacClure: In the Union National you can put on a gauge and batten it down. This is equivalent to saying floor is good for so much pressure. When the water raises to that point, start the pumps.

Mr. Knowles: Why doesn't the problem become a question of the relative difference between the fixed charges on a concrete and water-proof installation versus fixed charges and occasional operation expense on a pumping plant?

Mr. MacClure: It is a question of dollars and cents.

Mr. Schatz: You have to deal with the unreliability of men in this instance and then working 40 feet below ground; if fuel plays out or anything goes wrong, they are very liable to leave the property to the elements.

Mr. Knowles: You can put in a system where everything is worked from the top of the ground, with vertical shaft centrifugal pumps and waters at the top.

Mr. MacClure: It has been my experience that the nearer "fool proof" you can get anything about a building the better off you are.

Mr. Godfrey: There has not been anything said about the possibility of making the concrete itself water-proof. It is possible to make concrete that is practically water-proof.

Mr. MacClure: It is up to a certain pressure. At St. Louis they had a tank floating on a raft and containing about 20′ of water. But it is limited as to the amount of pressure it will stand.

Mr. Godfrey: It will stand 80 pounds. I think the expense you put on that water-proofing if it were put into making the concrete right, would have resulted in a far better job.

Mr. MacClure: I never heard of concrete standing 80 pounds. The most impervious mixture I know of is 1—2½—5.

Mr. Godfrey: It depends on the aggregate.

Mr. MacClure: In the tests made by Messrs. Moran & Rook in connection with several engineers in New York, they did not get anything like 80 pounds.

Mr. Godfrey: I cannot refer to the tests, but I have read of them.

Mr. Affelder: As a matter of fact, the total expense of the water-proofing is not very great?

Mr. MacClure: It cost about $8,500 in the Union National Bank building. The sub-basement floor is 35 feet from the average depth of the curb. They can put it in from 25c to 38c or more, depending upon conditions.

Mr. Godfrey: There is a building in this town in the flood district, and when they built the concrete they just threw the dry materials into the hole and the water coming up through there made the water for the mix, and they can keep that building pumped dry until the water runs over the top of the walls.

There were some tests made some time ago that stood 80 pounds. It was not concrete, it was a mortar made of cement and sand.

Mr. MacClure: I should have to see that test before relying upon it to that extent.

On motion a vote of thanks was extended to the author of the paper for his valuable and interesting address.

From a paper read before the American Chemical Society (Pittsburgh Chapter) and the Chemical Section of the Engineers' Society of Western Pennsylvania, October 17, 1907.

Old and New Methods of Galvanizing.

BY ALFRED SANG,*
Member.

HOT GALVANIZING.

Craufurd's patent of 1839 marks the advent of the hot process of galvanizing. It consists in dipping the articles to be coated in molten spelter. The temperature of the bath is in practice 425 to 480° C.[1] and the coating is bright and crystalline in nature. It is important that the articles to be coated be not withdrawn until they have reached the temperature of the bath, else not only will they be too heavily covered, but in cooling the very uneven contraction will lessen the adherence between the metals.[2]

The usual flux, which aids the process by removing the salts which may be left from the pickling, and causes the metal to flow properly[3] as it touches the iron and to enter the slight unevenesses of the surface, is sal-ammoniac. In the same way, sal-ammoniac brightens the surface of the work as it is drawn from the pot by causing it to flow. When hydrochloric acid has been used as a pickle it is not usual to remove it by washing, but the articles are immersed wet in the molten zinc. The acid converts the zinc with which it contacts into ammonium chloride and the flux is, therefore, the same. The occluded hydrogen, which is a natural consequence of the pickling, is presumably left in the surface of the metal and accounts for the trouble frequently experienced from hardness when the articles have not undergone baking.

* Vice Pres. of the Garland Nut and Rivet Company, Pittsburgh.

1 The melting point of zinc is between 412° and 434° C.

2 Lineal coefficients of expansion: Iron, .0000067; zinc, .0000292; ratio 1:45.

3 Sal-ammoniac is a solvent of zinc.

Sal-ammoniac, while it is a very effective flux, is also a very effective agent of destruction. The chlorine remains between the zinc coating and the metal, either as a chloride of zinc or of iron, or as hydrochloric acid; if it is present as a chloride it will in time, and especially if the articles are heated, be converted into hydrochloric acid, which is the best solvent of iron.[4] Unless exterior conditions are uncommonly unfavorable, hot galvanized articles break out into spots and it is found that the iron in these spots is already deeply rusted; it is the greater amount of space occupied by the rust which bursts the protecting coating of zinc. We galvanize for the enemies without and ignore the fatal chloride which we carefully sandwich between the zinc and the iron.

It is the flux which so rapidly destroys the galvanizing kettles. The dross contains a large amount of chlorides. I recently tested a small piece from just below the dross line of a kettle which had worn down from a thickness of 1 in. to 3/64 of an inch within a year, and the water in which that piece was soaked showed a considerable amount of chlorine. It is usually said that dross will eat out the iron of a galvanizing kettle but this is incorrect. Chlorides are not essential components of dross, they are present because we put them there. The metals and the oxides in the dross do not eat out the iron. The zinc may alloy itself to the iron to a very limited extent; on a piece cut from about 1 ft. above the dross line of the pot to which I have already referred, I could only find a few spots where the zinc may have combined with the iron, the surface had remained practically unaltered; lower down, where it had been eaten out by the decomposition of the chlorides, the zinc had evidently penetrated but not sufficiently to render the metal non-corrodible. That zinc dissolves iron may be true, if the conditions are right, but this theory does not come within one per cent. of explaining the destruction of galvanizing kettles, whereas the presence of the chloride in the dross, which any one can test with a few drops of nitrate of silver

[4] Chlorides when heated in the presence of moisture, and therefore all hydrated chlorides decompose, giving hydrochloric acid.

solution, explains it fully. By using chlorides as fluxes we gain in adherence but lose in permanence; it is a puzzling situation.

A hot coating is seldom, if ever, perfect, it almost invariably shows small cracks; under very high magnification it shows pin-holes, all of these imperfections being vents for the admission of corroding agents. When the articles are immersed wet, there are often small blisters caused by the steam which was imprisoned between the iron and the zinc. When the articles are bent they will crack although the cracks may not always be visible to the naked eye. An important defect is that the metal will bridge bad spots due to imperfect cleaning, and, therefore, conceal imperfect manufacture. The fumes of the process are injurious to machinery and necessitate a hood, but in most cases compel the erection of a separate building. There is a loss due to dross and skimmings[5] and the pot must be kept going day and night actually using up fuel 24 hours out of 10 in the majority of mills. The metal is not pure and is, therefore, more readily destroyed by acid and other influences; it contains some iron, especially if the spelter is not virgin, or worse still, if it has been "sweated" from dross in which the iron of the first spelter has been concentrated, the iron salts left by the pickle have been taken over, and the iron of the pot itself has been dissolved by the action of the flux.

Another drawback of hot galvanized work which is not as widely understood as it should be is, that it will not take paint readily; the surface is smooth and greasy to the touch. If galvanizing took a cheap and air-tight composition such as varnish, the problem would be half solved; the other half of the problem belongs to the domain of the chemists who will, no doubt, some day suggest to us a flux which will be wholly virtuous. The American Government specifies the preparation of hot-galvanized surfaces for painting by washing them with vinegar so as to roughen them.

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5 30% of the charge, or even more, worth about 80% the price of spelter.

It seems hardly right for me to criticise, as I have done, an old friend like hot galvanizing, while I am fully aware of the fact that for many purposes, and notably in its most important applications, it stands without a serious competitor whatever the future may reserve for the newer processes[6].

PICKLING.

Before going on to the next process I shall say a few words about pickling. The pickling process comprises two essential parts, one fully as important as the other. First comes the solution of the oxide, or its removal by the solution of the iron upon which it rests; secondly, the arrest of the action of the pickle and the cleansing of the surface pickled, in which I should include the neutralizing of the acid.

The magnetic oxide, or mill-scale, is the hardest to remove; it occurs in scales having small fissures scattered throughout their surface. This mill-scale is soluble in hydrochloric acid, but iron being sixty times more soluble, the scale is removed because the iron upon which it rests is dissolved. To say that scale is dissolved by hydrochloric acid may be scientifically correct, but in a manufacturing sense it is incorrect. As a matter of fact, the electrical contact-action of the scale increases the rate of solution of the iron and it is, therefore, doubtful if any appreciable amount of scale goes into solution until after it has been detached. However, the scale which falls to the bottom of the pickling tank will be worked on by the acid, unless removed.

Rust is not readily dissolved, if at all, but it is easier to remove than Fe_3O_4, because it occurs in a granular form and is less adherent. Articles covered with mill-scale if allowed to rust partially—not, of course, until deeply pitted—will pickle a great deal better and more economically.

Sulfuric acid is also used for pickling; it can be shipped in iron tank-cars and stored in iron tanks, but its popularity would surely wane if hydrochloric acid, which is more ef-

[6] An interesting work on the practice of hot-galvanizing is "Galvanizing and Tinning," by W. T. Flanders (David Williams Co.).

ficient and which does not pit the metal so deeply, could be handled in bulk instead of in glass carboys. There is no record of mill-scale being soluble in sulfuric acid.

Steel is composed of iron containing in solution various impurities such as manganese, sulfur, phosphorus, silicon, carbon (as graphite) and their salts. The carbides and especially *cementite* and *pearlite* are the most important impurities. Under certain conditions, notably when cooling, some of these impurities will be separated from the mass and remain imbedded as granular or crystalline eutectics[7] Quoting Prof. H. M. Howe: "From the microscopic study of polished sections iron (and steel) appears to be constituted like granite, and similar compound crystalline rocks, of grains of several distinct crystalline minerals of which seven common ones have already been recognized, through peculiarities of crystalline form and habit, color, lustre, hardness and *behavior towards solvents*."

As for the action of acid pickles in connection with these impurities I quote Prof. C. F. Burgess:[8] "It is known that with a given grade of iron one acid will leave a cleaner surface than another acid, and the reason back of this demands a study of the action of acids upon the various constituents of iron and steel. Often after the removal of the oxide from the surface a coating of more or less adherent particles will be found, which have a black, brown or grayish appearance, varying with the character of the metal. This deposit is commonly supposed to be due to the carbon which was originally contained in the iron." Whatever the composition of these particles may be, the fact remains that pickling always produces a certain degree of "rottenness" of the surface, especially with steel.[9]

Hydrochloric acid seems to dissolve out the impurities of steel quicker than does sulfuric acid and that is no doubt why

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7 For typical micro-photographs see: "Engineering Chemistry," by H. J. Phillips, pages 61-X, 61-W; Cassier's Magazine, Nov., 1903; App. B. to "The Materials of Construction," by J. B. Johnson, page 725; most important of all, E. Heyn in the Zeitschrift fur Elektro-Chemie, yr. 1904, page 491.

8 Electro-Chemical & Metallurgical Industry, Oct., 1905, page 386.

9 See "The Metallurgy of Steel," by Harbord & Hall, page 521.

the surface of the work has a better and smoother appearance. Various proportions of water are added to aid the action of the acid by dissolving and removing from the zone of activity the salts of iron which are formed. Heat increases the efficiency of the pickling solution to a great extent, especially in the case of sulfuric acid. Hydrofluoric acid is added when it is required to remove sand from castings. Soluble salts of copper are said to aid the action of acid pickles; arsenic has a very decided retarding action.[10]

To neutralize the action of the pickle, lime, sal-soda, and caustic-soda are most commonly used, but to make the cleaning perfect a powerful water spray, of 100 lbs. per sq. inch or more pressure, may be employed, this high pressure being essential. A sand-blast is better, wherever it can be used, since, in addition, it removes the "rotten" surface left on steel by the action of the pickle, and makes it firm for the reception of deposits. If the coating is to be non-metallic, the advantage of the sand-blast over every other method is indisputable, because not only does it thoroughly cleanse the surface, but it scores it, so that the non-metallic coating will "grip," and not flake off so readily when bent, thereby making up for its disadvantage of not being able, by reason of its nature, to form a continuous joint with the metal.

The removal or reduction of scale may be effected electrolytically; to quote from Langbein's well-known work on electro-deposition:[11] "Suspend the articles in a weak acid bath (hydrochloric or sulfuric), connect them with the positive pole of a source of current and suspend opposite to them a sheet of metal (copper or brass), which is connected with the negative pole."

Mr. Chas. J. Reed, of Philadelphia, has recently patented what appears to be a decided improvement on the older methods. In his process the articles to be cleansed are placed at the negative pole in a weak acid solution and the scale alone is

10 See "Arsenic in Pickling Solutions," a paper read before American Electro-Chemical Society, Sept. 19, 1905.

11 The "Electro-Deposition of Metals," by Langbein (Baird & Co.).

dissolved, the iron remaining unaffected. Presumably the nascent hydrogen reduces the oxide and the iron set free is instantly taken care of by the acid present. In the process of the Vereinige-Electrizitats Aktiengesellschaft of Vienna, the solution is alkaline; the work is the anode; the cathode, which is formed of carbon or some conductor not acted on by the electrolyte, regenerates the solution by forming more alkali which reprecipitates the oxide dissolved from the anode.[12]

THE COLD PROCESS.

The origins of electro-galvanizing—or cold galvanizing as it is often called—are very remote, but commercially it is a new process. The process itself has not varied much since its revival a few years ago; new patented apparatus is being constantly brought out, the value of which is usually much overrated; the business, in its present state, offers little encouragement to monopoly because the basic principles of the process are as much public property as are those of hot galvanizing. Solutions are innumerable, each one better than the others; most of them are of practically equal value—it all depends on who is put in charge of them.

In the electrolytic process of zincing, the work is the cathode and the regenerative anodes are made of "commercially pure" zinc. These anodes must be clean and of good quality and on this account and also because of the special shapes in which they are cast, they cost more than spelter. The residues of the process are a grayish powder which falls to the bottom of the vat and runs very high in zinc, and the tattered remnants of the anodes themselves; another waste product is the solution which must be run out periodically when through the admixture of foreign substances which are carried in by the work and also through what I might call "general disorganization," it becomes unworkable.

The cleaning of articles which are to be electroplated must be very carefully done, it is more costly than for any

12 C. F. Loppe, in L'Electricien, yr. 1900, page 106.

other process. The zinc being deposited ion by ion there can be no bridging of bad spots and the perfection of the coating is a proof that the articles were clean before being coated and is, therefore, a guarantee that it will live up to specifications. This is a most important consideration which only the more conscientious producers of electro-galvanized work can afford to advertize. In the case of hot galvanized work, the buyer has no means of ascertaining the true quality of the product until it is too late to make any claim.

Theoretically, nothing is simpler than electro-galvanizing; in practice, nothing is more uncertain. It is a mistake to think that all plants turn out equally good work. The job-galvanizers who really know their business can be counted on the fingers of one hand. There are more factors to take into account than in any other process and the margin between success and failure for each factor is very narrow. Firstly, comes the composition of the bath and its conductivity; secondly, the temperature; thirdly, the voltage and the current density; fourthly, the quality, shape and position of the anodes. A weak solution will give off a large amount of hydrogen and will produce a spongy deposit, especially if the current density is too low; such a deposit is worthless for permanent service. The conductivity is regulated by means of acid, or other additions. Different solutions require different currents and there is always a temptation to use too strong a current, which results in a deposit lacking in toughness. It must be remembered that, as the deposit increases in thickness, conditions change from depositing zinc on an iron or steel surface to depositing it on a zinc surface; the resistance is continually increasing. The anodes must be of such shape and so placed that each part of the work will be equally distant from them; the thickness of deposit will vary as the square of the distance from the nearest point of the anode. Some shapes cannot be electroplated at all unless the work be done in a revolving barrel; these barrels are necessarily made of non-conducting material, rubber or wicker, they must allow a free passage for the electrolyte, and

these requirements combine to make them lack strength and wearing qualities. Furthermore, the electrolyte must not be allowed to stagnate and the best way to keep it fresh and efficient is to so place the anodes in reference to the work that the path of the gas bubbles given off from the surface of the anodes will percolate the solution. In order to do this it is good practice to place the anodes at the bottom of the vats whenever possible, unless they and the work can be racked vertically. Cowper-Cowles has developed a method of regenerating the electrolyte by pumping it through a filter of coke and zinc-dust.

An electro-galvanized surface is attractive in appearance, although it is less bright than a hot-galvanized surface. Under the microscope it shows pores which are due to specks of impurities which prevented the depositing of the zinc. The contact between zinc and iron is perfect, and on this account, above a certain critical limit, an electrolytic coating is more efficient than a hot coating. One great advantage of the process is that there is no caking of the metal and the threads of bolts after galvanizing are clean, and ready to receive the nuts. The work will take a good polish, but it is not permanent because the zinc-iron couple is extremely active owing to the purity of the zinc, the excellent contact and the free access of atmospheric agents through the unavoidable pores. The more pores there are in the deposit, the more rapidly will the work cover itself with white carbonate.

A great deal of harm has been done the electrolytic process by the exaggerated claims of its early votaries. A great many plants have been installed to enable manufacturers to do their own work and many disappointments have followed. The process is still in course of development and it stands as good a chance as any other to become the best in the long run; at present it is not without some serious drawbacks, except for some classes of work which should in all cases be entrusted to specialists who treat the process with the respect which is due to it; it is a scientific process and cannot be carried out on the tonnage plan or by the sweating system.

ZINC DUST.

In the reduction of zinc oxide with carbon to produce spelter, from 3 to 10% of the zinc given off as vapor is condensed in the flues and prolongs in the form of a gray impalpable powder containing a few scattered bright beads of zinc. By analysis zinc dust, or "blue powder," as it is often called,[13] runs from 75 to 92% of zinc, from 5 to 20% of zinc oxide, the balance being lead, cadmium, sulfur and iron. The most usual percentages are from 88 to 90% of zinc and about 10% of oxide. There are no free particles of zinc oxide, but each little sphere of zinc seems to be oxidized, hence its gray color and its now obsolete name of gray zinc oxide. The reoxidization of the zinc when the dust is formed is attributed to aqueous vapor and the carbonic dioxide of the furnace gases. As near as I can measure, zinc dust particles are in the neighborhood of 1/50,000 of an inch in diameter and apparently all of practically the same size. Zinc dust must not be confounded either with zinc oxide nor with the skimmings of furnaces, other than the Belgian type, in which prolongs are seldom used, which skimmings are also known as "blue-powder."

The specific gravity of zinc dust is difficult to determine, but it is, on good authority, said to be 10% lighter than cast zinc; or, say, about 6.2; it is, however, so fine that it is as easily blown about as the lightest powder.

Zinc dust is not by any means welcomed by the furnace man; he tries to produce as little as possible, because there is practically no demand for it and he must resmelt it. The percentage of dust could be readily increased if required, by keeping the condensers cool and keeping down the proportion of reducing gases, and a patent has even been taken out on a process for producing it to the exclusion of spelter. Imperfect condensation in the electric smelting furnace will also produce it. The Montefiore furnace was at one time used for the recovery of zinc from zinc dust. The process consisted in melting the dust without fuel in a fireclay cylin-

13 German: Zinkstaub; French: poussiere de zinc, gris de zinc.

der under pressure. A charge of about 50 lbs. of dust was heated for five hours with the piston resting on it, after which pressure was applied and the zinc squeezed out of a side outlet at the bottom of the retort.

What little zinc dust is used in the United States for miscellaneous purposes comes from Belgium or Northern Germany, there being no import duty and the consumption being a few hundred tons per annum only. Paint manufacturers use the dust to a limited extent and it enters into the composition of fire-works for producing blue stars. Under the name of "indigo auxiliary" it is made into a paste for printing cotton goods by discharging the color of the dyed fabric; this is effected at the temperature of boiling water.

It is this affinity of zinc dust for oxygen at a low temperature which makes it impossible to melt it into slabs under ordinary conditions. As I have mentioned elsewhere, electrolytic zinc does not melt easily and the reason has been given that it is because each particle is oxidized; the same reason is brought forward to explain the difficulty of melting zinc dust. While there is undoubtedly some truth in the contention it does not solve the entire problem, as I shall endeavor to show.

The chemical activity of zinc dust as compared with zinc in other forms, is quite remarkable and not fully explained by the small dimensions of the particles and comparisons with spongy platinum. Douglas Carnegie[14] found that where a certain process of dechlorination took several hours with zinc-foil, zinc dust acted instantaneously. He also found that even in neutral solutions, zinc dust instantly reduced ferric to ferous salts. He stated that in the latter case the action was far more rapid than with granulated zinc in the presence of sulfuric acid, but after discussion he rejected the theory due to G. Williams to explain this remarkable efficiency. Williams had shown[15] that zinc dust decomposes hot water very rapidly and cold water more slowly, absorbing hydrogen, but giving it up on being heated, also that it absorbed

14 Transactions of the Chemical Society, London, 1888, page 468.
15 Chemical News, Vol. 52, various places.

hydrogen at ordinary temperatures in the presence of moisture, yielding 50 times its volume of the gas when heated alone or 535 times its volume when heated to redness with an equal weight of zinc hydroxide. This action of zinc dust on water is surprising when contrasted with the fact that strips of zinc will not have any action whatever on cold water even after several years[16] and its action on hot water is only very slight.[17] Copper hastens the process by setting up favorable voltaic currents. The theory offered that the oxide which quickly forms on the surface of the strip zinc prevents further action carries no excuse for the activity of the zinc dust which is already provided with a coating of oxide.

This absorbed hydrogen has no doubt some relation to the reputation of zinc dust for spontaneous combustion. A fire on board the S. S. Lord Clyde in 1877 is supposed to have originated in a barrel of that substance, some of its contents having been spilled on the dock, rained on and replaced in the cask. It was claimed that after the fire had been extinguished by means of a hose, the contents of one of the casks was found to be *red hot*; of course, such unscientific behavior on the part of the zinc dust justified the court in ruling against it, and it is, therefore, classed in New York City and in other communities as "dangerous."

Explosions of zinc dust have occurred on several occasions just as explosions of coal dust and other fine dusts do, but the metal itself, when dissolved in acid, is liable to cause accidents, as shown by the following, which I quote from Harris' Technological Dictionary of Insurance Chemistry:

"Explosions from this source have been caused at different places, as, for example, at the chemical works of Ludwigshafen, where they frequently happened in dissolving large quantities of zinc in hydrochloric acid, in the manufacture of zinc chloride, without the air of the workroom coming in contact with the fire. It was substantially proved that these explosive fires were spontaneous. Hofman explains the pheno-

[16] Boutigny: Annales d'Hygiene Publique, Vol. 17, page 290, yr. 1837.

[17] Cooke. Jaresbericht, 1854, page 359.

menon as follows: 'The hydrogen gas evolved raises the zinc, made very porous by the action of the acid, above the surface of the liquid, so that the finely divided zinc, in contact with the air and hydrogen, causes, like spongy platinum, the inflammation of the gas mixture.' The same experience was had, before the occurrence at this works, at the works of Schering, in Berlin, but could not at the time be accounted for."

Some recent experiments of W. Heald[18] would seem to show that hydrogen would not be absorbed by zinc dust during its condensation from the vapor. He found that when some metals, including silver, plantinum, aluminium and cadmium, were vaporized in an atmosphere of hydrogen, the condensation was accompanied by an absorption of hydrogen which proceeded some time after the temperature had fallen, but of all the metals with which he worked zinc alone failed to show any absorption. This property of zinc dust of absorbing hydrogen, is, therefore, shared neither by the massy metal—except possibly by the action of an acid pickle—nor by the vapor.

Zinc dust reduces carbon disulfide with incandescence and if pounded in a mortar with flowers of sulfur will detonate, if heated together they will combine violently to form sulfide of zinc, although when the zinc is in any other form the combination will be comparatively slow and laborious. As a general thing, it can be said that where zinc is useful as a reagent, zinc as dust will be more efficient than in any other form. For instance, it is used as a substitute for zinc shavings in the precipitation of gold from the solution obtained in the cyanide process.

Zinc appears to give off vapors at very low temperatures, hence its well known action on photographic plates, which zinc dust shares with it, but to an even greater extent, as I have recently found. This activity of zinc may be of the same order as that of the so-called radioactive elements and their salts. H. S. Allen's observations on the photo-electric fatigue of zinc[19]

18 Physical Review, March, 1907.

19 Royal Society Proceedings, Series A, Feb. 2, 1907.

show that the decay of activity after a plate of this metal has been polished, corresponds very closely to the formula for decay of radioactivity and permits the assumption that, as in the case of radium, two main radiations and an inactive residue are given off. Zinc sulfide blackens a photographic plate, but no action is observed if it is encased in celluloid, just as in the case of radio-lead. [20]. The zinc ion has also a very strong coagulating action, and as S. Leduc has demonstrated,[21] an anode composed of zinc or of a zinc chloride solution will rapidly take a deposit of albumen from its solution when little or none is deposited by platinum and other metals.

The peculiar properties of zinc dust have by some been attributed to cadmium, which is present in quantities of from ¼ to ¾ of 1%. Cadmium being more volatile than zinc distills during the early part of the smelting operation and, therefore, at the time when most of the zinc dust is formed, it is almost all condensed with it in the flue-dust. This appears to me to be a convenient straw, but there is no evidence to show that it will float the answer to the question. Antimony dust acts in the same way as zinc dust and I have also found that the flue-dust of the copper converter will deposit copper, but it will not adhere properly and the great amount of sulfur present makes it very inconvenient to handle.

I have suggested a reason for the peculiar behavior of zinc dust and since I first published it[22] I have found no cause to change my belief. My theory may be entirely wrong, but it has at least served as a valuable working hypothesis on which is founded the latest process for galvanizing by means of zinc vapor.

It is natural to try to explain the nature of a substance by examining its mode of production. Zinc dust is produced by the sudden cooling of the vapor of zinc, and the transition from the gaseous to the solid is so rapid that for all practical purposes the liquid state is skipped. The setting of matter

[20] L. Vanino. Journ. Prakt. Chemie, 1906, page 446.
[21] Archives d'Electricite Medicale, Dec. 25, 1906.
[22] Electro-Chemical and Metallurgical Industry, May, 1907.

when caused by a sudden chilling causes abnormal brittleness because the molecular structure is disarranged; this is notably the case with the glass Rupert tears which are so unstable that the slightest shock will shiver them to powder. Molecular disarrangement due to premature setting renders the material liable to disintegration under conditions less severe than are required when the structure is normal. In the case of zinc dust particles, the outside surface is set first and for convenience may be compared to a skin; the interior which would take up more room, because it is not enclosed, is set in a state of strain; a rise in temperature of 100° C. or so will increase this strain to overcome the resistance of the surface tension. It is reasonable to assume that on account of its sudden cooling zinc dust is physically unstable and that as a consequence a low heat by causing expansion will shiver it to vapor, which in the presence of oxygen will immediately turn into the oxide.[23].

It is worth noticing that the oxide produced by zinc dust is flocculent and fibrous like that obtained by burning zinc vapor (hence its name, "philosopher's wool"), and the traces left by zinc dust particles which I have oxidized on glass slips and examined under the microscope lead me to believe that the oxidation takes place explosively. A parallel case is Ozone, which is also unstable and a very active bleaching agent; it is likewise produced by violent physical methods; it is an abnormal condition of oxygen, an unstable allotropic modification.

The breakdown of zinc dust reproduces the phases of its creation in reversed order. Being released as a vapor without liquefaction—being if you wish, carried over that stage by the momentum of its physical breakdown—when its powers of affinity are called upon to assert themselves and to perform a reaction, it is not surprising that it acts instantaneously where the stable form which can only offer comparatively little surface of contact, has to be "coaxed."

In the various compositions containing zinc dust which

23 The boiling point of zinc is between 916° and 942° C. An appreciable vapor tension has been detected at 184° C.

are used for calking cracks and flaws in castings, packing steam joints or smoothing over metallic surfaces, the gentle heat which is applied releases the zinc vapor in the body of the mixture where it cannot oxidize on account of the vehicle which is usually an oil;[24] it becomes a continuous solid or more exactly an emulsion in which the zinc plays the part of the emulsive.

SHERARDIZING.

In 1902 Mr. Sherard Cowper-Coles, of London, patented a process for galvanizing metal goods by packing them in zinc dust in an air-tight retort and heating the retort to a temperature below the melting point of zinc. This process is known as sherardizing; it is used to a limited extent in England and Germany, but has not yet been introduced into this country. It has been suggested that the failure to acclimatize the process on this side within six years of its discovery is due to some radical defects which have been kept in the background, but to the best of my knowledge the reasons are of a very different order, the process itself is all that it is claimed to be, wherever it can be conveniently applied; I also believe that if the royalties had been placed at a figure commensurate with the economies which the process is likely to effect it would have become more widely known and more widely used several years ago in the land of its birth.

Even if, through poor management and continual delays, the process is destined to be a commercial failure, this does not in any way alter the fact that sherardizing is for many purposes, and especially for small articles, a well-marked improvement over both of the older processes. In regard to appearance, quality and low cost, it excels both the hot and electrolytic methods.

In practice, articles to be sherardized are placed in an iron or steel drum and are covered with zinc dust to which is added a little charcoal dust, which prevents undue oxidation, and the drum is then placed in a furnace and kept for some time—

24 Usually a vegetable oil.

from 30 minutes to several hours—at a temperature of 300° C. or more. The thickness of coating will vary according to the time during which the zinc dust in contact with the work is kept at the proper temperature.[25] On account of the variations in the size of the drums and the articles to be coated, it is very easy to get too thin a coating in one case and too heavy a coating in another; the coating may be made so heavy that all the economies of the process are wiped out and the balance shifted to the wrong side. There is nothing, however, in the actual work which cannot be grasped by the intelligence of an ordinary workman; the actual labor can be performed by anyone; there are none of the fine points to be kept in mind which make the electrolytic process so delicate. A recent improvement[26] has been the addition of sand, which is said to yield a better-looking deposit and prevents caking. The zinc forms a continuous body with the metal of the article, it penetrates the iron or copper and in the latter case the result in the zone where the metals mix is brass, where in the former it is a hard and bright zinc-iron alloy.

In appearance sherardized work resembles electro-galvanized work, but it is of a slightly different shade of gray and darker. As you have noticed from the samples, it takes an exceptionally good polish, which, unlike that of electro-galvanizing, is permanent. The zinc-iron alloy is very hard and resists acids better than either of the metals by themselves. Sherardizing, when properly done, will resist corrosion far better than hot or electric work; the covering is close and continuous and free from blisters or pinholes.

There is practically no waste of zinc by this process; there is necessarily some slight oxidation of the dust, but the percentage of oxide may be allowed to run very high before the dust becomes unworkable. A slight drawback lies in the fact that to obtain proper economy of labor it is necessary to design a special plant for each different class of articles and if the articles touch, the retort must be so built that it can be

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25 The drum is not coated because it is hotter than the articles.

26 Due to Mr. Gauntlet, of London.

revolved or its position changed from time to time. There are, on the other hand, a great many advantages to offset these; grease or oil from the fingers will not give any trouble; the work can be put in wet; it takes paint or enamel fairly well; articles of tempered steel, such as springs, are not affected by the low heat employed; the plant can be made ready for use on short notice, and the zinc coating will draw with the iron or steel when put through a die, as in the case of wire drawing and in the manufacture of sheet-metal ware. However, the process cannot compete with hot galvanized work which is wiped, such as fence and telegraph wire and band iron; work galvanized continuously, either by the electric process, or the hot process when it can be wiped, cannot be sherardized at as low a cost, and it is doubtful if galvanized sheets could be handled as cheaply.

In my paper read before the American Foundrymen's Association at Philadelphia last May, [27] I reviewed in detail the advantages of sherardizing in the following particulars. The initial expense and depreciation, the amount of zinc used, the labor, the fuel and power, and the supplies; I do not think it is necessary for me to repeat all these shop details, but if any of you are interested in them I would refer you to that paper. I have nothing to add to what I then wrote and only regret that since that date no progress whatever has been made in placing the process within reach of the manufacturers.[28]

VAPOR GALVANIZING.

The credit attaching to the first attempt to coat metals by means of zinc vapor appears to belong to a Frenchman, Jean Pierre Chambeyron, from whose English patent, granted

[27] "The Art of Galvanizing," see Transactions of the American Foundrymen's Association; or the Iron Age, May 23rd and 28th; or The Foundry, July and August; or the Scientific American Supplement. ment.

[28] See also "The Metallic Preservation and Ornamentation of Iron and Steel Surfaces," by S. Cowper-Coles; a paper read before the British Soc. of Engineers, Nov. 6, 1905.

in 1864, for "Improvements in protecting iron and steel against oxydation," I quote the following extracts:

"My invention consists in causing metallic vapours to penetrate into iron and steel to prevent their oxydation * * * By my invention I incorporate into iron or any oxydable metal in a state of metal vapours, either zinc alone when the contact of oxygen is only to be counteracted, or a volatile combination composed of 18% of tin, 12% of lead and 38% of zinc * * * I obtain such results by placing the iron heated to a very high temperature in a non-oxydating medium, by converting into vapours the protecting metal, and by causing them to penetrate into the iron by powerful pressure * * * (the furnace is then described) * * * The metals to be incorporated into the iron are poured in a molten state into the funnel, and thence falling into the retorts are instantaneously converted into gases on account of the high temperature within the retorts. If the pressure created by the gases formed from the metals should not be sufficiently powerful to complete their incorporation into the iron, the degree of necessary pressure can be easily procured by obtaining from the gasometer the required supply of non-oxydating gases which are always therein stored. When the metallic vapours have strongly penetrated into the pores of the iron they will condense by lowering the temperature in the retorts; this must be preceded by the introduction in the retorts of a certain quantity of borax, which by its volatilizing will fix the incorporated metals * * * *Claim* * * * the mode of protecting iron, steel, and other metals from oxydation arising from the oxydating medium into which they are placed, by incorporating into them the vapours of several metals not oxydable, produced at a high temperature and under a pressure greater than that of the atmosphere."

Since then, nothing of especial interest has been brought out, although last year Cowper-Coles secured a patent on a process for ornamenting or coating metals by means of vapor and by using hydrogen and borax; his patent is hedged in by

the limitations which necessarily arose from the ghost of the late Mr. Chambeyron's invention.

Metallic vapors have also been suggested, if not used, for coating the filaments of incandescent electric lamps; in such cases a vacuum and high temperatures are employed.[29]

Quite recently, Zenghelis[30] has supplied some very valuable data on the evaporation of metals at ordinary temperatures, which are, therefore, true for all higher temperatures below the point of fusion. In his experiments the metal to be tested was enclosed in an air-tight glass vessel with a sheet of chemically pure silver foil suspended horizontally about one-quarter of an inch above it. Several metals, zinc among others, volatilized very appreciably. The presence of moisture and the reduction of pressure favored the evaporation which was evidenced by the silver foil turning to a golden or other tint on account of the vapor absorbed and alloyed. It took weeks, and months in some cases, to produce results. The important fact was brought out that no action took place where the metals touched and the natural inference is that the metallic vapors were in a dissociated condition.

The more finely a metal is divided, the more readily will it volatilize; its activity in that respect is a function of its free surface. If, in addition to a large proportion of exposed surface, you have a state of physical instability, such as I have assumed zinc dust to possess, you have ideal conditions for ready dissociation under easy conditions.

The origin of the latest process for using zinc vapor is due, firstly, to the investigation of the nature and properties of zinc dust, and, secondly, to an endeavor to get away from one of the drawbacks of Sherardizing, which makes it impracticable for large work, namely, that the articles be buried in the dust.

When I became satisfied as to the volatilizing of zinc from zinc dust at low temperatures, I tried to obtain a coating

29 See English patents, No. 2558, of 1882, to J. S. Williams, and No. 2437, of 1906, to H. Zerning.

30 Zeitschrift Phys.-Chemie, Oct. 23, 1906.

by immersing copper wire in the vapor, but obtained no appreciable result. It then occurred to me that I might be able to fix this vapor by means of oil and I tried the experiment by dipping the wire in some mineral lubricating oil; within a few minutes I had obtained a silvery deposit. In this experiment there was no reducing agent or carbon mixed in with the dust, and the part of the test-tube in which the wire was placed was comparatively cool; the temperature of the flame must have been between 600° and 700° C., or more than 300° below the boiling point of zinc; the wire which passed through an asbestos plug was in contact with my hand; the zinc dust which remained was slightly oxidized on the surface by the air contained in the tube, otherwise it was unchanged. I realized the commercial value which my observation might possess and, I may add, that patents on the broad principles involved have already been allowed in the United States and in Belgium. Since then I have done a considerable amount of experimental work, with varying success until recently, and if good progress has been made in gradually converting the principles involved into practical results, it is in great measure due to my collaborator, Mr. Joseph J. Miller.

You have seen the samples of vapor galvanized pipe;[31] their general appearance is that of bright electro-galvanized work.[32] In a strong light these samples show a slight irridescence on account of the extremely fine grain of the deposit. We find that the zinc vapor will deposit under rust, showing that the process is not an exact counterpart of the electric method where a free straight path is required between the zinc and the article.

The laboratory apparatus used for securing data on the process was as follows: a small Skidmore crucible, or re-

[31]The coating on this pipe is light, having been treated but a short time to show the nature and closeness of the deposit and not to meet the usual tests.

[32]Other samples shown were a vapor-galvanized bolt; several sherardized screws, two of them polished; electro-galvanized bolts and castings by the Meaker Co., Chicago; electro-galvanized conduit by the Safety-Armorite Conduit Co., of Pittsburgh; a hot galvanized radiator section by the Pressed Radiator Co., of Pittsburgh.

tort, was connected by means of a long ¼-inch brass pipe with a coating chamber made up of a piece of 1½-inch iron pipe, 6 inches long, and two caps; the crucible was heated from below to anywhere from 400° to 900° C., but the best results were obtained at or below 600°. Below 400° the distillation was too slow. In the crucible, zinc dust and finely divided carbon or some other reagent containing carbon, and other additions, were placed in suitable proportions; the best practice is to have a larger volume of the reagent than of dust and there is no loss from oxidation or from reduction in the mass. The air can be left in the retort and coating chamber; it probably plays a part in the process by furnishing oxygen for the formation of carbonic oxide, which reduces the oxide on the zinc dust particles, releasing the zinc vapor, which can then condense in a suitable atmosphere. If the temperature is allowed to run too high, re-oxidation by the carbonic dioxide present is to be feared. You will notice that the new method bears the same relation to the older methods of coating by means of vapor which Sherardizing bears to the hot galvanizing process; Sherardizing is carried out in contact with zinc at a temperature below the melting point of the normal metal, vapor galvanizing is performed out of contact with zinc at a temperature below the boiling point of the normal metal.

The coating chamber does not become very hot, most of the heat it receives comes by the conduction of the apparatus. The internal pressure being very small, a non-conducting connection and valve between the generator and coating chamber could be used. There does not seem to be any advantage in heating the articles to be coated.

The mechanical advantages of the process over Sherardizing appear to be as follows: The generating kettle is small and need not contain more dust than is necessary for a day's run, or even less; it can be brought to the proper heat very rapidly and held there by means of a thermostat if fired with gas. There is no excess of dust to heat up and then to cool down and no weighty drum to handle to and from a furnace.

A cast-iron coating chamber, suitably lined, and resembling a vacuum drying oven, minus the special fittings, will hold anything up to a full day's production of a plant. The equipment being fixed is subject to less wear and tear. The articles as they come from being cleaned can be placed on suitable trucks, rolled into the chamber and be allowed to soak in zinc vapor for three hours or more, so that it will penetrate thoroughly.

More than one coating chamber can be used in connection with one kettle having several outlets and valves. As soon as the time of soaking is up, the chambers can be opened without loss of dust, as in Sherardizing, because the valve will keep the air out of the kettle. There is no limit whatever to the size of articles which can be treated and an entire bridge member would not be an impossible piece to tackle. One style of plant would do for every kind of work and one chamber would do for anything within its capacity. The racks, trays, hooks, etc., would be made of wood or of metal suitably protected by some material which would not take a coating of zinc.

The time required to get a satisfactory coating will vary according to the nature of the surface and the composition of the metal, and users would have to figure the surface of their "charge" against the capacity of their generator.[33] Mr. Miller and I have obtained much quicker results with other reagents than carbon, but various drawbacks were found, among others the pressure created by volatile reagents. A concomitant of the failure to obtain a satisfactory coating was in all cases the reduction of the zinc dust in the kettle and therefore the production of a by-product, zinc, more valuable than the original dust. I do not doubt but that before long a reagent will be found which will enable the distillation to proceed more rapidly, but it may be at the expense of the quality of the product. When cooling takes place very rapidly and the pressure of the zinc vapor is high, crystals of zinc are de-

33 The same problem exists as in electro-galvanizing; at first zinc is alloyed to iron, later zinc is deposited on zinc.

posited, but they do not adhere well and, while they are curious and interesting, they represent a waste. On non-conducting surfaces, such as carbon, the zinc is condensed as a dew of bright beads. With some reagents, such as coal-tar, an outer deposit of carbon is obtained which is very attractive and has the advantage of giving a good surface for the reception of a varnish or enamel—an ideal combination—but the results have so far been very irregular and this line of investigation has been abandoned for the present.

The zinc vapor when given off, at, say, 500° C., is below its normal critical temperature and it will readily condense and invariably select the coolest spots; if metals and non-metals are present it will condense on the metals and all the more readily the nearer the specific heat of the metal is to that of zinc vapor. Zinc vapor condenses more readily on copper, which has got practically the same specific heat in the solid state, than on iron. The reason for this selection is by no means clear to me and is more likely due to some other quality which bears a more or less constant ratio to the specific heat, such as the atomic weight or the intrinsic electrical potential.

The percentage of the diluting gas and its purity, must play important parts in the process, just as they do in the case of the regular reduction process of which vapor galvanizing is a counterpart, zinc dust being used in place of oxide, and the temperature being much lower and applied from without.[34]

At the temperature of the new process neither zinc metal nor zinc oxide would give useful vapors. The efficiency of finely divided carbon at these low temperatures is readily accounted for; very pure carbon will take hold of atmospheric oxygen below its point of incandescence, in fact, as low as 200° C.[35]

Articles galvanized by means of vapor do not reach even as high a temperature as in Sherardizing and they fill the popular demand for "bright stuff." There are no residues and no

[34] Similarly, in the case of an electrolyte, the degree of dilution of the zinc salt is of prime importance.

[35] Abbe Senderens, Comptes-Rendus, Feb. 18, 1907.

loss from dust blowing about while being handled. There is every reason to hope that vapor galvanizing will soon take its place in the metal industries as a powerful antidote for corrosion.

VARIOUS APPLICATIONS OF THE NEW PROCESSES.

Both of the latest processes for coating metals, Sherardizing and vapor galvanizing, suggest themselves for a number of new and valuable applications which were out of the question with the older methods. To galvanize fly-screening by placing it in the roll in a coating chamber sounds almost too good to be true. Boiler tubes can be given a coating which will not only safeguard them on an oversea journey but will lengthen their existence, for it is well known that scale will not adhere to a galvanized surface; if hot galvanizing cannot be made to render this service it is for reasons which I have already stated; hot galvanizing when heated is an agent of destruction on account of the flux which decomposes to hydrochloric acid and eats away the iron.

A light coating of zinc by either process is a better foundation for nickel-plating than copper; zinc and nickel adhere very closely and when alloyed are difficult to separate, even a small proportion of nickel seems to increase the resistance of zinc to volatilization to a very great extent.[36]

If aluminium is Sherardized it will solder and it can also be electroplated quite readily, taking the usual polish; the silver-plating of certain hard aluminium alloys which have first received a zinc vapor treatment may prove of interest for many articles. In this connection I would state that silver which has received a short treatment before polishing is said to resist the action of sulfuretted hydrogen.

An attractive development of Sherardizing has been the inlaying and ornamenting of metals. The designs are obtained by limiting the action of the zinc by means of a stopping-off varnish. The edges of the patterns are not sharply defined, because the vapor will work under the edge of the

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36 A. R. Haslam, Chem. News, Vol. 51.

stopping-off composition. While the results are lacking in contrast the general effect is artistic and pleasing at close range.

CONCLUSION.

Time does not permit me to discuss the comparative efficiencies of different zinc coatings; these efficiencies depend entirely on the nature of corrosion and it would be worse than presumption on my part to either propound or theorize on the subject of corrosion, when I can refer you to Allerton S. Cushman's thorough treatment of the subject.[37]

A German authority[38] has given it as his opinion that the value of zinc as a protection is due to its tendency to form an alloy with the iron; this is not an explanation, but it points to one. If the iron of a zinc-iron alloy is less readily dissociated in the presence of oxygen and of acids or other agents which supply hydrogen, the efficiency of Sherardizing is explained. The reason for the resistance of iron thus alloyed would seem to be due to the contact effect between the zinc and the iron whereby the potential of the iron is increased at the expense of the zinc. The zinc becomes more sensitive to corroding influences, whereas the iron which is, so to say, over-saturated, resists decomposition.

The proper place to search for further improvements in protective coatings for iron and steel is in the study of the true causes of corrosion. In order to discover the remedy we must study the disease.

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37 Dept. of Agr. Bulletin No. 30 (1907), "The Corrosion of Iron."
38 J. Spenrath.

PROCEEDINGS OF THE

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Vice President J. K. Lyons
In the Chair.

The Proportioning of Steel Railway Bridge Members.

PAPER BY HENRY S. PRICHARD.*

DISCUSSION.

C. D. Purdon† (*by letter*): In reading this paper the first impression is that it is not necessary or desirable to calculate safe working stresses on the available strength of steel while the provision for dynamic effect of live load (or impact) is such an uncertain quantity.

The great range of the impact observed in the B. & O. tests, as quoted in the author's paper, and the equally wide difference of opinion shown in the formula for impact proposed to the American Railway Engineering and Maintenance of Way Association in 1905, show that our knowledge of the effect of impact is, to put it mildly, indefinite.

Could we figure accurately the effect of a load statically and the effect of impact added to this, we might perhaps feel justified in using somewhat higher unit strains than we use at present.

* Published in July Proceedings, p. 324.
† Cons. Engr. S. L. & S. F. R. R.

Experiments now being made by Prof. Turneaure will, it is hoped, increase our knowledge of this subject, but apparently it will never be very definite—the effect of impact will be complicated by unbalanced drivers, producing extra strain alternately on either stringers, by flat wheels, by vibration and by possible derailment and for safety the highest of these must be used.

On page 333 the author says it is difficult to get engineers to commit themselves as to the greatest working stress they permit in an existing bridge before they condemn it. The writer does not consider it possible for an engineer to say what working stress is safe as a general rule. Old bridges, of course, are principally meant in this connection. In a great many cases the original drawings or records of the bridge are lost, but it is not possible to say what the material in the bridge is. The date of building would be an indication to some extent as to whether it is iron or steel, but the quality of it is unknown. The details of the structure are also of great importance. In some cases these are so bad that a span would shake to pieces under loads producing comparatively low unit strains. The behavior of the span under traffic is an important factor, also its physical condition as to rust, wear of pins, loose rivets, etc.

The position of the bridge with respect to the gradients should be noted. It may be in such a place that trains cannot well slow up.

Again, the character of the stream is important. If it be such that false work cannot well be maintained, the span should come out sooner than it otherwise would.

Again, we do not know what is the safe working stress when considered as a load plus impact. Are we to take the formula proposed by the author, or one of the seven proposed to the American Railway Engineering and Maintenance of Way Association? The results differ too widely.

The writer would consider that each span on account of its condition, design and workmanship is a problem by itself and the strain to allow, a matter of judgment, and that to pre-

scribe a certain number of pounds per square inch as safe under all conditions, either with or without some of the impact formula, would not only be misleading, but in many cases cause danger if used blindly by some man in authority who only possesses a smattering of bridge knowledge. Indeed, the quotation on the cover of Cooper's Specifications applies well here.

The statement on page 348 that if bridges had been proportioned for heavier loads 25 years ago, they would have remained in service much longer is undoubtedly true; but what would have been the effect from a financial standpoint?

The writer has looked up some old records of weight and prices and finds that in 1883 a through Pratt truss of 103 ft. 6 in. span weighed 121,000 pounds and cost $5.92 per 100 pounds delivered, not erected. A span of the same length today, but for a loading of about Cooper E-50 under the American Railway Engineering and Maintenance of Way specifications, would weigh 183,300 and cost about $3.00 delivered.

Supposing the original span had been designed for E-50 we would have paid

183,300 ℔s. at $5.92	$10,851 36
Instead of	
121,000 ℔s. at $5.92	7,163 20
Extra cost heavy span	$ 3,688 16
24 years' simple int. 5%	4,425 84
Cost of original span today	$ 8,114 00
Compare	
183,300 ℔s. at $3.00	5,499 00
Loss by building heavy span originally, counting simple interest only	$ 2,615 00

J. P. **Snow*** (*by letter*): In reference to the feature of allowable unit strains in existing bridges, the author is undoubt-

* Civ. Engr., West Summerville, Mass.

edly safe in recommending 20,000 lbs. per in. in connection with his proposed scheme of impacts. The statement in the paper that the "public recommendations (of engineers) in this regard are liable to be more conservative than their practice" is quite true. Much that has been written on this subject is very vague. To be of value, however, a statement should be definite and it should embody just what we believe.

My experience leads me to believe that old bridges of normal proportions and in good physical condition may be trusted under trains at 20 miles per hour when the unit strains are about twice those ordinarily used in designing new work. At 60 miles three-quarters of this figure should be the limit. This is a very broad general rule and it should be tempered with a careful study of the action of the structure under loads and with a knowledge of its past history.

The type of bridge has considerable influence in fixing upon the proper limit. Plate girders merit the confidence that all repose in them. Riveted trusses stand next, and well proportioned pony trusses of this class behave better with me than through trusses. Pin trusses built 30 years ago will not bear the unit strains that riveted trusses of the same age will.

To judge if an old bridge is suitable for increased loading is a much more difficult task than to pass on the safety of a bridge for existing traffic. Both timber and metal bridges will show signs of distress a long time before failure need be feared under existing traffic. If it is desired to increase the loading, an engineer can learn much by a study of similar structures that have shown signs of weakness under known loads, and can judge by the strain sheet what will probably be safe on the bridge in question. No hard and fast rule can be laid down, however, because no two structures behave exactly alike. The above rule of double the ordinary units, with traffic at moderate speeds, is the best that I can offer for a basis to be used in conjunction with close study in the field.

A. F. Robinson* (*by letter*): In reference to discussion on Mr. Prichard's paper as to bridge specifications, I find that

* Bridge Engr., A. T. & S. F. Sys.

with the time at my disposal I will not be able to give the discussion that I feel it deserves and that I should like to make. I cannot agree with Mr. Prichard's conclusions and a good many of the assumptions which he is giving as principles.

As to the formula for impact, it seems to me that this is only adding another set of guesses to an already very long series of same. There are now, I think, twelve or fifteen, perhaps more, formulas for impact allowances which are used more or less. It does not seem to me that Mr. Prichard's arrangement is any nearer correct than the others; in many respects it does not seem to meet the general requirements as the formula of Mr. C. C. Schneider. A few years ago I noted Mr. Prichard was recommending an altogether different formula for impact.

During the past year the American Railway Engineering and Maintenance of Way Association has been carrying on an extended series of tests to determine the effect of impact on our bridges. These tests have been made under the hands of Prof. Turneaure, of the University of Wisconsin. The tests have been made in series and a great many of them taken. With these tests there can be no possibility of drawing erroneous conclusions from a few single erratic tests. The number of tests made by Prof. Turneaure and his assistants the past season are probably ten or twenty times as many as all the others previously made, which are referred to in Mr. Prichard's paper.

It is my understanding that these impact tests are to be continued the coming year by the M. of W. Association. During the coming season they expect to make tests on bridges having ballasted floor and on other bridges, which are as near exact duplicates to the above as possible, with open deck. I would suggest that it be wise to hold up final discussion and conclusions regarding Mr. Prichard's paper until such time as the record of the tests already made by the M. of W. Association can be available.

F. E. Turneaure* (*by letter*): Mr. Prichard's letter on "The Proportioning of Steel Railway Bridge Members" sets forth

* Dean of University of Wisconsin.

in an unusually clear manner the fundamental problems relating to the design of bridge members. The writer is in close agreement with the general deductions of the paper, but in the hope of contributing somewhat to the discussion, which doubtless will be exhaustive and very valuable, he would offer some comments relative to certain minor features.

It has been customary with the writer to state the general problem of the determination of the cross-section of bridge members in a slightly different way from that adopted in the paper, and which seems to be a more logical statement. The writer would state the problem as follows:

1. Determination of available strength of material.

2. Determination of the real maximum stresses, so far as practicable, to which the material will be subjected. This includes impact, or dynamic effect, and provision for increase of live load. It may also include in some cases secondary stresses, but these would not be in general calculated.

3. The selection of a working stress to apply to the total calculated stress. This working stress must be less than the permanent elastic limit of the materials to provide for the following:

(a.) Defects in material and workmanship; (b) Deterioration of material; (c) Uncalculated stresses such as secondary stresses. This item may also include impact, but preferably not. (d) Contingencies.

The writer believes that a classification, such as above outlined, is logical and lends itself readily to developments in analysis and design. As our knowledge increases concerning such matters as impact and secondary stresses it would seem that better results would be secured by taking care of these items under the head of stress determination rather than in the selection of a working stress. The author's statement on page 331 appears somewhat confusing on this point, as the term "defects" seems to include impact which, however, is separately considered later. The question of logical arrangement is, of course, not of fundamental importance to the experienced engineer as it would not be likely to modify the final result.

The writer would suggest, however, that it is quite important that the item of secondary stresses should be specifically enumerated in the paper, as these stresses are often important and will doubtless be given increasing consideration in the future.

The conclusions which the author derives from his theoretical case of impact do not seem to cover the ground. He has presented a formula for a particular case and given in Table No. 6 some numerical results. Following this table are certain deductions which, the author points out, do not agree with the popular belief. The principal deductions in question are to the effect that an increase of weight of structure increases the impact, while an increase of weight of dead load, not a part of the structure, reduces impact slightly. Perhaps this matter can be cleared up by a more detailed examination of the formula and numerical results. Referring to cases 2, 3 and 4 of the table, it will be seen that the only element which varies is the width and weight of the rectangular beam. The impact increases with the increase in size of beam. Noting again, cases 5 and 6 the external distributed load is increased and the impact is thereby slightly reduced. Again in case 9, as compared to 8, the beam is doubled in depth, but halved in width, leaving its weight the same. The impact is greatly increased. Now the fundamental cause for these results is that in the problem assumed the impact is increased whenever, for any reason, the *stiffness* of the beam is increased. An increase of stiffness reduces the deflection, the effect of which is to increase the impact, as is evident by inspection of the formula. An increase of *weight*, however, either in the beam or in its load, without any change in stiffness, causes a decrease in the impact. Stating the results in this way, they seem to be strictly in accordance with experience, and assist materially in understanding the essential effects of weight and stiffness.

A flexible structure is evidently a better form to absorb the energy of a blow than a stiff structure, and hence the impact ratio will be less in the former than in the latter case. In railroad bridges, the impact, or general dynamic effect, is

due to two distinct causes, as the author points out. (1) The sudden pressure or blow due to rapidly applied loads, centrifugal force of counter-weights, effect of rough track, etc. (2) The vibration resulting from repeated applications of impulses at regular intervals. In short spans, the first-named causes are the only ones of importance; in long spans it is the second group. The first group corresponds roughly with the theoretical case considered; the second group is not covered by the analysis. The correct conclusions would therefore seem to be that in the case of short spans impact is increased with increased rigidity of structure between wheel and masonry, and is somewhat lessened by increase of weight, other things being equal. This statement corresponds with experience as is indicated by the belief in the cushioning effect of ballast and in the use of wooden wall plates, and other means to give greater flexibility in short spans. On the contrary, in long spans the main impact effect, as regards truss members, is caused by the vibration of the entire structure. In this case it is reasonable to suppose that additional weight will tend to reduce the impact, and that increased stiffness may also have the same effect. On these points, however, there is as yet little or no data from which conclusions can be drawn.

In his treatment of impact, with direct reference to the selection of a formula, the author has used the available results of experiments in a conservative manner and has reached conclusions which, to the writer, appear to be reasonable. It is proper to say here that the American Railway Engineering and Maintenance of Way Association, through its committee on Iron and Steel Structures, is undertaking an extensive series of impact tests which it is hoped will throw more light on this subject. During the past summer experiments have been made on some fifteen structures under very favorable conditions. In all cases special test trains were furnished by the railroad company, thus making it possible to make a large number of comparative tests in a short time. A progress report of this work will appear during the coming winter in the publications of the association. It is expected that a much more extensive series of tests will be made during the next year.

J. W. Schaub* (*by letter*): This paper has been presented at an opportune time, so that it has attracted considerable attention. The author's conclusions as to the available strength of structural steel, and his proposed safe loads in tension and compression are to be commended, especially the percentages to be added to members liable to alternate stresses. In members of this kind, the author makes a distinction in favor of riveted connections, as compared with pin connections, owing to the play in pin holes and their tendency to enlarge, which should be observed. However, members liable to either tension or compression should not have any part of either stress added to the other, unless this reversal occurs during the passage of one train.

The author says that the yield points for structural steel in tension and compression do not differ greatly, but he subsequently makes his safe load in compression 1,000 lbs. less than in tension. This is a wise provision, as it is well known that the yield point in compression is sometimes as much as 10 per cent. less than what it is in tension. In this case the yield point in tension has probably been raised at the expense of the yield point in compression by the internal stresses that exist in all steel, due to shrinkage in cooling, so that it is logical to use a lower value in compression than in tension, so that the writer would suggest that this be 14,400† instead of 15,000 lbs. This forms the base for a column formula given later by the writer.

It is doubtful if the increase in the train load has been more potent in determining the lives of railway bridges than all other causes combined. This may be true on the trunk lines in the East where bridges were bought on a pound price basis, but in the West, in the early days, when bridges were bought on a lump sum basis, on plans submitted by the bridge companies themselves, some terrible blunders in design were made; and, even now, the writer would say that the design

* Cons. Engr., S. L. & S. F. R. R., Monadnock Blk., Chicago.

† This value for the safe compression on structural steel was obtained by deductng 10% from 16000=14400 lbs

of a bridge is more potent in determining its life than all other causes combined.

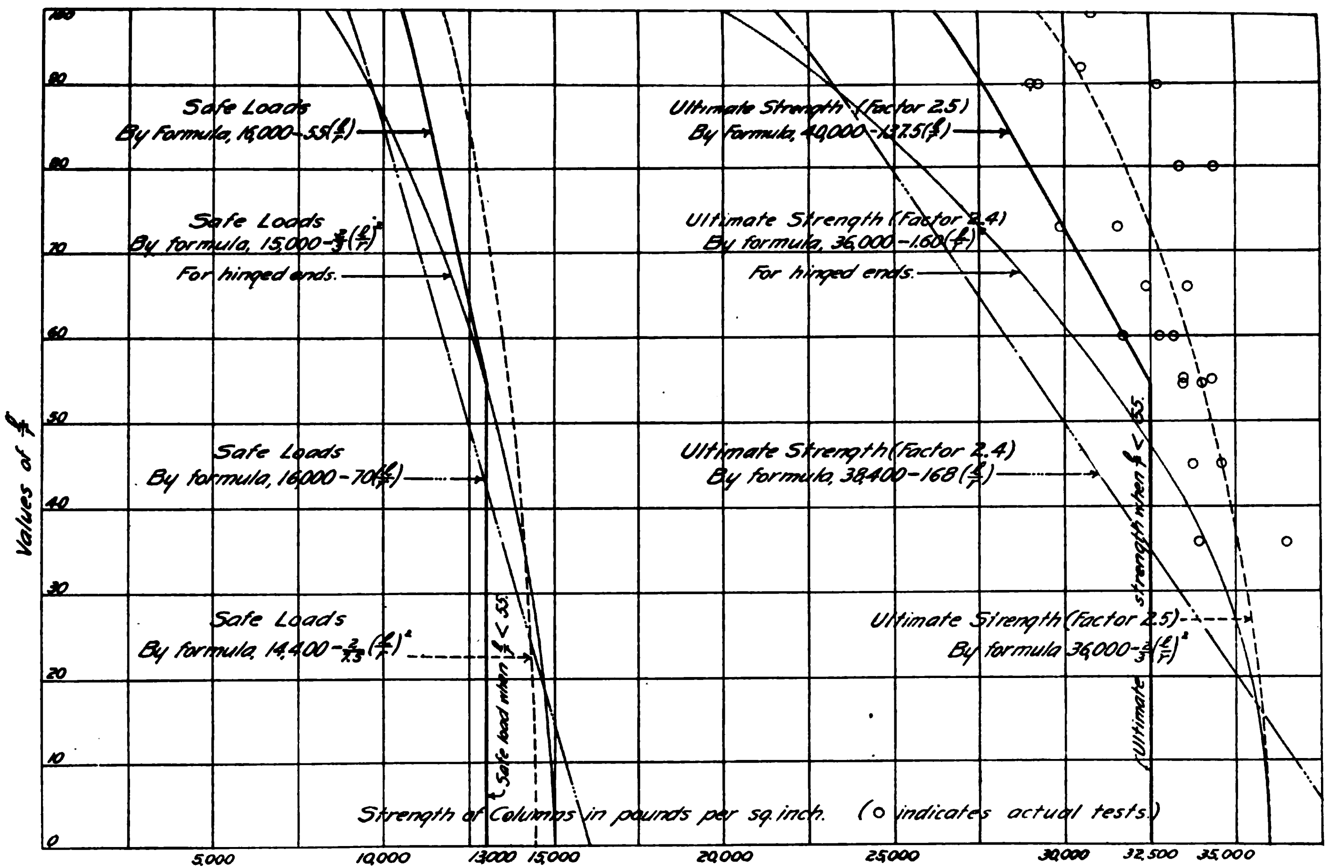
There are imperfections in all designs, more or less, but there is one vital defect in our designs for truss spans which is not usually provided for, in this country at least, and that is the effect produced by the eccentric connections of the floor system to the inside faces of the truss members. These eccentric connections produce secondary stresses of no small importance, when it is considered, that in some cases these secondary stresses are greater than the primary stresses, so that the author should make some provision for them in the proportioning of bridge members, or at least recognize them.

The recommendations as to the safe loads on members in existing bridges, so that the tension shall not exceed 20,000 lbs. intensity, after a proper allowance for impact has been made, are to be commended. Of course, the question at once arises, what allowance for impact shall be made. The author takes up this question subsequently, but here it might be said that for all spans under 200 feet long the various impact formulas in use give practically the same results, so that it is immaterial which formula is used for such investigations.

The arguments offered by the author for a consistent method in designing compression members are admirable, but he should limit the length of his columns for practical reasons solely. A long and slender column is more liable to faulty alignment during fabrication, and more liable to accidental injury by handling than a heavier column, so that very frequently the designer must use a heavier column than that which the load calls for. This comes up frequently in the top lateral bracing for ordinary spans, especially when the design is such that these struts can actually take compression from the moving load owing to the shortening of the top chord panels. Anyone can observe that such is a fact by keeping his eye on these members during the passage of a slow and heavy train, and if the diagonal bracing is such that it cannot take the load which comes on it, it will shirk its duty and permit more or

less vibrations to occur. If the author does not wish to limit the length of his columns to 100 radii, why not make the limit say 120 radii of gyration? His own argument against long and slender columns should prescribe some limit, at least; for, as he says, they will fail under loads which will produce only very small stresses from direct compression, and are more liable to faulty alignment. To be sure, the column formula given by the author practically eliminates long and slender columns, but it frequently happens, in bracing, that a column is required to carry little or no direct load, whereas a certain stiffness is required in any event, so that a larger column must be used than is required by theory alone.

The diagram herewith shows the column formula for hinged ends, $15{,}000-\frac{2}{3}\left(\frac{l}{r}\right)^2$ proposed by the author, for safe loads, and also for the ultimate strength, using a factor 2.4, or $36{,}000-1.6\left(\frac{l}{r}\right)^2$. On the same diagram, the formula of the Am. Ry. Eng. & M. W. Ass'n, 1906, is given $16{,}000-\frac{70\,l}{r}$ for safe loads, and also for ultimate strength, using the same factor, 2.4, or $38{,}400-\frac{168\,l}{r}$. A number of full size tests on columns are also given. These tests were made at the Watertown Arsenal on wrought iron columns composed of two channels, latticed, during the years 1880-1883 inclusive. The results show that the formula proposed by the author gives values nearer to the actual tests, for lengths under 90 radii, than the formula of the Am. Ry. Eng. & M. W. Ass'n. Above 90 radii in length, the formula of the author will require much heavier sections than any formula now generally in use. This is as the author intends. The averages of the results of the full size tests on wrought iron columns follow the formula, $36{,}000-\frac{2}{3}\left(\frac{l}{r}\right)^2$ approximately, so that using a divisor of 2.5, a formula for safe loads should be $14{,}400-\frac{2}{7.5}\left(\frac{l}{r}\right)^2$. For lengths of 60 radii this formula would give a safe load of 13,434 lbs. per sq. inch, instead of 12,600 lbs.



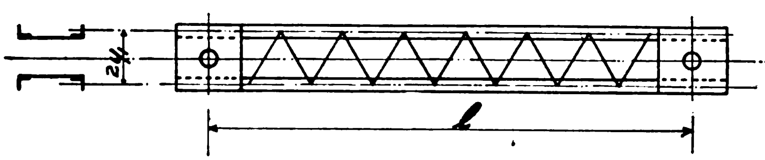
Values of $\frac{l}{r}$
Safe Loads
By Formula, $16{,}000-55(\frac{l}{r})$
Safe Loads
By formula, $15{,}000-\frac{1}{3}(\frac{l}{r})^2$
For hinged ends.
Safe Loads
By formula, $16{,}000-70(\frac{l}{r})$
Safe Loads
By formula, $14{,}400-\frac{2}{7.5}(\frac{l}{r})^2$
Safe load when $\frac{l}{r} < 55$.
Ultimate Strength (Factor 2.5)
By Formula, $40{,}000-137.5(\frac{l}{r})$
Ultimate Strength (Factor 2.4)
By formula, $36{,}000-1.60(\frac{l}{r})^2$
For hinged ends.
Ultimate Strength (Factor 2.4)
By formula, $38{,}400-168(\frac{l}{r})$
Ultimate Strength (Factor 2.5)
By formula $36{,}000-\frac{2}{3}(\frac{l}{r})^2$
Ultimate strength when $\frac{l}{r} < 55$.
Strength of Columns in pounds per sq. inch. (o indicates actual tests.)
0
10
20
30
40
50
60
70
80
90
100
5,000
10,000
13,000
15,000
20,000
25,000
30,000
32,500
35,000

FIG. 1.

given by the author. For lengths of 90 radii, the safe loads would be 12,235 and 9,600 lbs. per sq. inch respectively. On the same diagram there is also given a new formula to which the writer wishes to call attention. It is given at the top of the sheet, for safe loads $16{,}000 = \frac{55l}{r}$, and for ultimate strength, using a factor 2.5, or $40{,}000 = \frac{137.5l}{r}$. This formula is due to Mr. G. H. Blakeley, M. A. Soc. C. E., and has been adopted by the Bethlehem Steel Company, and is published in their handbook for 1907, just issued. The writer calls attention to this formula inasmuch as it meets the results of the tests better than any formula yet proposed, giving values that are on the side of safety in all cases. For lengths under 55 radii the safe load is 13,000 lbs. per sq. inch for all cases. The writer calls attention to this formula as it deserves the highest consideration.

In designing a compression member, the proportioning of the lacing has become quite as important as the section of the body of the member. Assuming the formula for hinged ends, $15{,}000 - \frac{2}{3}\left(\frac{l}{r}\right)^2$ as given by the author for safe centrally applied loads, the reduction due to flexure is assumed to be due to a transverse load, uniformly distributed and of an intensity w, producing an incidental bending moment

$$W\Delta = \frac{wl^2}{8}$$



Let l denote the length of the member.
Let A denote the sectional area of the member.
Let f denote the fibre stress due to bending.
Let $2y_1$ denote the distance c. to c. of rivet lines.

Then $\frac{wl^2}{8} = Afy_1 = A\frac{2}{3}\left(\frac{l}{r}\right)^2 y_1$

Assume $y_1 =$ radius of gyration $= r$, then

$$\frac{wl^2}{8} = A\frac{2}{3}\frac{l^2}{y_1} \therefore \frac{wl}{2} = \frac{8Al}{3y_1} \quad \text{.....................................(1)}$$

The end shear is assumed to be carried entirely by the lacing, one-half on each side, so that the lacing on one side would be the same as if the member were laced on two sides. This means, of course, that a member having a balanced section with a cover plate on one side would require the same lacing on one side as though the member were open on both sides. This may seem unfair to the member having a cover plate, but it is rational in case the lacing is designed for its duty. In order to make the lacing three times as strong as the body of the member, so as to provide for all contingencies, excepting perhaps an intentional eccentric loading,

Equation (1) becomes $\frac{3wl}{2} = \frac{8Al}{y_1}$ ....(2)

Eq. (2) gives the end shear which comes on the lacing when the column has reached its ultimate strength, or three times its safe load.

Let S denote the stress or load which comes on the axis of the lattice bar, and $2y_1$ the distance center to center of rivet lines; then,

For single lacing on either side at 45° $S = \frac{5.65\,Al}{y_1}$ ....(3)

For single lacing on either side at 60° $S = \frac{4.61\,Al}{y_1}$ .....(4)

For double lacing on either side use $\frac{S}{2}$

Equations (3) and (4) give the load which comes on the bar, when the proper size of bar can be selected. Usually the number of rivets required at the end of the bar determines its

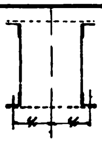
width, whereas the unsupported length determines its thickness. The table herewith (Fig. 2) gives the above formula and the values of flat bar as struts up to a length of forty times their thickness. Example:—

Assume a member 50 ft. long, having 50 sq. inches, $y_1 =$ 11 inches, then for single lacing on either side at 60°,

$$S = \frac{4.61 \times 50 \times 600}{11} = 12{,}600 \text{ lbs. on each bar.}$$

This requires 2⅞ in. diameter rivets at each end, requiring a bar 5 inches wide, whereas one-fortieth the distance between the end rivets requires a bar ⅝ inch thick, or 5 in. × ⅝ in. bar.

LOAD OR STRESS ON LATTICE BARS OF COLUMNS AS DERIVED BY FORMULA AS FOLLOWS:



Let l denote the length of member in inches
" $2y_1$ " " distance between rivet lines in inches
" A " " sectional area of member
" S " " load on lattice bar in lbs.

For single lacing on either side at 45°, $S = \frac{5.65Al}{y_1}$
" " " " " " " 60°, $S = \frac{4.61Al}{y_1}$
" double " " " " use $\frac{S}{2}$

PERMISSIBLE COMPRESSION ON FLAT LATTICE BARS

By Formula $p = 15000 - \frac{1}{8}\left(\frac{l}{r}\right)^2 = 15000 - 4.5\left(\frac{l}{h}\right)^2$ for fixed ends
in which l = length of bar c to c of end rivets in inches
h = thickness of bar in inches = not less than $\frac{l}{40}$.

Values given are ⅓ ultimate strength, in lbs per sq. inch of bar, in compression

Thickness of bar h	Length of bar l	15"	16"	17"	18"	19"	20"	21"	22"	23"	24"	25"	26"	27"	28"	29"	30"
	l^2	225	256	289	324	361	400	441	484	529	576	625	676	729	784	841	900
⅜"	h^2 = 0.141	7800															
7/16"	0.191	9700	9000	8170													
½"	0.25	10950	10400	9800	9170	8500	7800										
9/16"	0.316		11350	10880	10380	9850	9300	8700	8100								
⅝"	0.391				11250	10850	10400	9920	9450	8910	8390	7800					
11/16"	0.472							10800	10380	9950	9500	9040	8550	8060			
¾"	0.563									10770	10400	10000	9600	9200	8750	8300	7800

FIG. 2.

The ill-effects of a possible increase in live load are not as serious, as the author believes if the design is properly made in the first place. In bridges with curved or broken chords the effect of an increase in the live load is a very serious matter as regards the counter stresses, inasmuch as they are augmented by the increased chord stresses; but, in all ordinary cases for members liable to a reversal of stress, if in designing such members, only 70 per cent. of the dead load be considered as effective, the results will be quite satisfactory. Taking the cases given by the author; the *first member*, an eye bar carrying no dead load would naturally be strained higher by an increase in live load, in a direct proportion, so that this case should be eliminated. The *second member* is certainly able to carry an increase of 25% in live load, as the author says. The *third member*, if originally only 70 per cent. of the dead load had been considered, this member would have been under a normal stress of 16,000 lbs. per sq. inch with 25% increase in live load, as follows:

Third member—(Counter rod)

Live load and impact	+192,000 lbs.
Dead load	—160,000 lbs.
Maximum	+ 32,000 lbs.

Area required at 16,000 lbs.=2 sq. in.

As it should have been designed

Live load and impact	+192,000 lbs.
Dead load 160,000×0.70..................	—112,000 lbs.
Maximum	+ 80,000 lbs.

Area required at 16,000 lbs.=5 sq. in.

With live load increased 25%.

Live load and impact	+240,000 lbs.
Dead load	—160,000 lbs.
Maximum	+ 80,000 lbs.

Tension per sq. in.=16,000 lbs., as before.

The *fourth member* comes in the same class with the third member, and if only 70 per cent. of the dead load had been considered in this case, the member would have originally been designed as a compression member. The above shows that it is only in such members that are liable to a reversal of stress that an increase of the live load becomes a serious matter, so that the writer suggests that in such cases only 70 per cent. of the dead load be considered as effective. This is the rule in the specifications of the American Railway Engineering and Maintenance of Way Association adopted in 1906, and will meet all requirements for some time to come.

Regarding the provision for the dynamic effect of the live load, or impact, this matter is now being investigated by the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, so that it would be better not to come to any conclusion in this matter until after the committee has made its report.

The author has touched upon many features in the design of railway bridge members that are new, and his paper should be well received.

The Chairman: The paper is now open for general discussion.

Geo. S. Davison: I have not taken the opportunity of reading Mr. Prichard's paper, but even if I had done so, I am so rusty upon the subject of bridge construction that I doubt if I would have been able to criticise it in any particular. My last experience in railroad bridge work dates back to the time when a load of 30,000 pounds from a pair of driving wheels of a locomotive was considered the limit. However, I note that the gentlemen who have been reviewing the paper, through the written discussion read this evening, are generally in harmony with the writer, and that speaks well for the paper.

While I do not have anything to say upon the particular subject of the paper, the idea of bringing the designs of steel railroad bridges under such methods of precision as are reasoned out, both in the paper itself and the discussion thereon, leads me to say, that from what I know of the splendid work

of our bridge engineers, and what I have seen (and perhaps felt) in the many miles I have traveled over railroads in all parts of the country, I feel safer as my train is whirling over an up-to-date bridge than while on any other part of the railroad. I make that remark in a general sense, as it would not apply to some few of the best railroads, whose officers and engineers are consistent in their plans of making everything safe.

Upon a great many railroads the engineering department is treated only as a necessary evil. Upon such roads there is perhaps but one item of the railroad's physical condition over which they are given any responsibility, and sometimes with the responsibility goes very little jurisdiction. I refer to the care of the steel bridges. They may, perhaps, in new extensions of lines, be given full charge of surveys, design and construction to completion, but so far as the maintenance of old lines is concerned, the tracks, buildings and even the wooden substructures may be under the care of men of no technical education or experience. It is customary for the general officers of such railroad companies to consider the large streams crossing their lines as the most dangerous points on said lines, and when the structures for such crossings are carefully designed and erected, be content that everything else is all right. Any effort on their part to make the steel bridges safe for traffic is to be commended, but when the intelligence and fine work of the engineer is confined to that one thing, while the rails, ballast, stations and trestles are neglected, it would appear to be very like a case of a chain forged for a severe service with but a link here and there possessed of sufficient strength. More than once upon railroads whose names stand for great transportation systems, and whose engineers take up just such subjects as this paper tonight, and in discussion work out fine-haired theories as to the effect of the impact upon a structure of a flat wheel, I have seen pile and framed bents carrying the track above them when they were so far decayed or crushed that it would not seem possible for another car to pass over them safely. This is certainly straining at a gnat and

swallowing a whale, and a thing of which no engineer should be guilty, provided, of course, all is within his jurisdiction.

The paper of the evening throughout urges safety. It points out the great care which should be had in designing the bridges for our railroads. This suggests another thought. The engineer should feel his responsibility to the management and the latter its responsibility to the public. With this responsibility should go a judicious expenditure of money, the latter a little lavish perhaps in cases of doubt. Dividends to the stockholders of the railroads should be a secondary consideration to the safety of the line. I firmly believe, notwithstanding what I have recounted as having seen, in most cases it is made so, and especially where an engineer is at the helm. However, upon thousands of miles of railroads in this country it has been a close call for the management to secure sufficient sums from operation to maintain their properties, and that with a wave of prosperity upon them. What do you suppose they can do, that, while still retaining their responsibilities, the various State Legislatures throughout the land, without the slightest knowledge of the problems of railway income and expense, undertake to prescribe the maximum charges that said roads shall receive for their services? If such things can stand the question of constitutionality, great economies on these struggling railroads must be practiced and that may result in a partial disregard, at least, of the safeguard for public life and property. I am not arguing against legislation that arises out of an intelligent, fair and exhaustive study of the subject. Just such legislation directed towards the railroads is perhaps needed, but the main trouble about working out and apply rules of behavior for public service corporations is that there is no responsibility upon the side of legislation for the failure of the rules, due either to their weaknesses or their application. If the public who demands a voice in the management of corporations can be made to bear the responsibility of its acts, experience will bring about a better understanding of the duties the public service corporations and the public owe each other. This may mean governmental ownership, but with all its faults, it is far better than this indiscriminate irre-

sponsible tampering with the earning power of railroads, and the consequent lowering of the standards of safety that must necessarily follow in some cases. Governor Hughes, of New York, while recognizing the necessity of public control over public service corporations, had the courage to call a halt upon that sort of legislation, which gives us some encouragement to feel that in that State may be worked out plans for the government of public utility corporations that will guard the public safety and financial interests, while at the same time allow reasonable returns upon the capital invested.

Some of the remarks just made may seem out of place in discussions among engineers, but I contend that engineers are vitally interested in all questions pertaining to the relation of public service corporations to the people they serve, and they should discuss them just as fully as they would the adaptation of the forces of nature to the uses of mankind.

Morris Knowles: I notice in one or two places the statement that a difference between long and short spans causes a change in the effect of impact, as to whether stiffness or weight helps or hinders. I would like to ask whether anyone has stated, or can anyone present state, where the line is drawn between long and short spans, where this change occurs? Again may I ask whether with the heaviest locomotives, with the gauge now used, are we not somewhat near the loading limit of the soil in ordinary ground?

Col. T. P. Roberts: I am not known to any of my friends as a bridge man. Nevertheless, I am very much interested in the paper and the remarks which have been made. It seems to me that now is a very appropriate time for bridge engineers to go over the formulae and the mechanical part of the work, especially in view of the serious disaster we have recently had on the St. Lawrence, and about which everyone is thinking, no doubt. In reading along these lines I notice very little said about the metallurgical possibilities of the subject. Bridge engineers do not seem to be in as close touch with metallurgical engineers as they were a few years ago. It seems to me they have gotten into a rut of structural steel of a certain grade as being the thing, and they use it without further considerations.

We know that the failures of steel rails have attracted the attention of those poor unfortunate millionaires who operate the railroads, and their attention has been attracted to the importance of doing something better with the materials entering into the making of the rails. I do not see why they have not got around to material for bridges also. In one of the recent proceedings of our Society I recall a paper on vanadium. Of course, the use of vanadium adds to the cost, but it might be used in certain parts, especially those where great vibration occurs. As I recall, it is simply remarkable how many more blows steel bars can stand with a very small amount of vanadium in them than without it. With the advance in the weights and speeds of trains, better material should by all means be introduced into bridge construction, regardless of cost.

Louis P. Blum: The statement is made on page 347 of Mr. Prichard's paper that 50% increase in load is an ample factor. Doesn't that figure seem rather high? Of course, it is impossible to forecast the future, but with the present construction of roads, where would we put any 50% increase over present maximum loads? We cannot increase the width of the freight car, because its present width is just about maximum with the tracks at 13 ft. centres. We are limited as to present heights of freight cars by the road clearances, and it would seem that we have reached almost the limiting length of freight trains. Therefore 50% increase over present maximum loading, especially for short spans, would seem more than the present construction of roadbeds would allow. Would not future increase of freight traffic be handled by more trains rather than by longer or heavier trains?

A Member: In case of trains derailed on bridges, isn't there great danger of the locomotive striking the trusses and causing a collapse of the bridge? And has anything ever been done to guard against that failure by putting in guard rails or such things?

J. K. Lyons: If I may make a few remarks from the chair, as I did not expect to be called on to preside tonight, I will say that I happened to be looking into this feature of increase in

loading on a prominent system that has a number of bridges in use that were constructed thirty years ago. The towers were 30 ft. and the spans between towers 60 ft. The tower spans were king post trusses, pin connected; the 60 ft. spans were Fink truss spans. The engine loading at that time was two 55-ton locomotives with possibly 1500 to 2000 lbs. for the train load. The same road is using two locomotives of 178 tons followed by 5000 lbs. for train load, today. A viaduct that is replacing this old viaduct will weigh about 3.6 times as much as the one that was put in about 30 years ago.

On another system, in another part of the country, they put in some bridge work twenty years ago which is now being taken out. It was figured for engines of about 92 tons followed with a uniform load of about 3000 lbs. The road is using engines of about 150 tons followed by a train load of 5000 lbs., so that you can see about what the increase in loading has been for thirty and for twenty years.

In 1888 or 1889 a 60,000 lbs. capacity gondola was quite a heavy car. We used to stop and look at it when we saw it out on the line. It was not long until the 100,000 lbs. capacity car came in, and as a matter of fact there are steel cars being built today with 120,000 lbs. actual capacity, and I think the roads permit about 10,000 lbs. overload.*

You can figure on 135,000 lbs. for live load on steel hopper cars today, so it is pretty hard to make a prediction as to what the increase will be. It is quite probable that locomotives will go up to 200 tons. In fact, there are in use today locomotives of about 192½ and some of 196 tons with about 6000 lbs. for the train load. As a matter of fact, for the 100,000 car it is equivalent to about 4700 lbs. per running foot.

In reference to what Mr. Davison said in regard to wooden culverts, I think that is the most treacherous part of the line. I know it is a source of worry to the railroad men and will undoubtedly produce the worst wreck.

In another line of investigation in regard to bridges, I have received information from men that have had considerable experience in examining old structures, possibly built

* Ten per cent. is the rule.

under the conditions Mr. Schaub states in his discussion, that the weak point is almost invariably in the floor beams and stringers. This might be the case, for the reason that if they were built on the lump sum basis the connections were figured to the letter of the specifications. The truss members apparently will stand a much heavier percentage of increase of load than the floor system. At least, that seems to be pretty well authenticated from information that has been given to me by men that have made a study of the old structures.

There is one point in the paper which you, who have not followed bridge designing, may not have noticed, and that is in regard to the use of the impact formulae. Take a long span bridge and in designing it, if it has 25 ft. panels the stringers will be figured as a 25 ft. span, which will naturally make them heavier; and in the same way with stringers, if the span is 200 ft. you should not use the stresses you would get if you had a 200 ft. span, and using the impact formulae. Take some of the older specification say for this floor system they provide for decreasing the unit strain 25% in determining the section from that used in determining the truss members, and for the field connections of the floor system the stresses were decreased 33%, in that way they increased the margin of safety very materially. I am inclined to think that a bridge which was figured with a low unit strain, the details figured on that basis, are probably standing an increase of load pretty well. In fact, one of the bridges I had reference to, was built thirty years ago, the cantilever bridge over the Kentucky River, which bridge is undoubtedly taking heavier loads over it today than it was figured for.

With reference to the tie, I do not believe it is overstating the case very much to say that it is about one-third narrower today than it was thirty years ago, and I do not believe the quality is as good. In regard to the derailed train striking the trusses, it is certainly a grave danger. What is generally used to provide for conditions of that kind is the Latimer guard rail. (Mr. Latimer was Chief Engineer of what is now part of the Erie System.) They are rails that are laid inside the main track and run out beyond the bridge possibly 100 ft. and come

together in the centre of the track. The wooden guard rail on the outside is flared. The idea is that in case of a derailment they never will get out more than half the gauge and when they strike the guard rail they are supposed to be pulled back and running between the guard rail and the regular rail pass over the bridge without striking the structure. If that precaution is not there, they will hit the structure and probably cause collapse. It is a remarkable thing that the bridge does not always go down. I know of a case where the cars got out far enough to strike the suspender and destroy it and still the train passed over and did not cause the stringers to go down.

Gerald E. Flanagan: In regard to car capacity, many cars fully loaded appear only about half full. This applies to cars loaded with ore and machinery, to say nothing of pig iron, steel billets, etc. There is plenty of room for more if the construction would permit of putting the weight on it.

Ralph C. Wood: Some time ago I was connected with one of the prominent railroads in the East and a matter came up of a certain manufacturing company that desired to load a car with 125,000 ℔s. The railroad replied that the maximum limit they were allowed was 115,000 ℔s. The only thing they were afraid of was the flanges. The strain of the wheel would be increased if the load was increased.

A. Stucki: In regard to increasing the width and height of a car, we do not need to make provisions for some time to come, as this would necessitate widening the track gauge, a thing which certainly will be out of the question for many years to come.

Mr. Prichard: The paper under consideration has drawn extensively for facts and analysis on the previous investigations of Prof. Turneaure and it is gratifying to learn that he is in close agreement with its general deductions. Prof. Turneaure's suggestion that the item of secondary stresses should be specifically enumerated is a point well taken and is adopted. The working stresses recommended in the paper were chosen with the intent to allow sufficient margin of safety for the ordinary run of secondary stresses, and stresses from defective

material and imperfect workmanship. Cases will arise, however, for which special provision should be made. It is quite difficult to lay down specific and reasonable rules and for this reason the speaker avoided the subject, as he did not care to weaken the rest of the paper by giving either an inconclusive consideration or a purely arbitrary one.

In deciding whether or not special provision for secondary stresses is necessary in any given case, reliance must be placed on the judgment and ability of the engineer. To aid his judgment in this matter special studies, both analytical and experimental, are needed. As a result of such studies it may in some cases be possible to lay down approximate rules, which should be as simple as possible. A few cases in which studies may be of great assistance may be mentioned. The bending stresses in posts to which floor beams connect (the failure to provide for these stresses is, as Mr. Schaub puts it, "a vital defect in our designs for truss spans"); the bending of floor beams and the stresses in stringers produced by the endeavor of the floor system to share in the chord stresses; the stresses in the end connections of floor beams and stringers produced by the effort of the connections to fix the ends; and the bending in chords from the deformation of the trusses. To some extent it is possible by intelligence and care in design, fabrication and erection to partially avoid secondary and unintentional stresses and to thereby achieve the advantage of the certain "old salt," who when asked how he would navigate a vessel in certain trying circumstances, replied, "I wouldn't get in such a fix."

Cases may arise in which it is advisable to adopt unit stresses to suit the occasion, which seems to be Mr. Purdon's idea, but for the great majority of cases it is convenient, at least, to have a definite specification giving specific working stresses. For old bridges the case is different, but even for them it is well to have certain stresses established as a danger signal to mark the entrance of the bridge into the "uncertain class" which are awaiting renewal and being watched in the meantime. In this connection the condition and behavior of old bridges are of great importance and the discussion of this

point by Mr. Snow and Mr. Purdon merits careful consideration.

The stresses which sound the danger signal for old bridges are of use, when designing new ones, in making wise provision for possible increase in loads. The most economical provision for increase in live load will be achieved by proportioning each member by the highest unit stress permitted in an old bridge. The method given in the paper is based on this principle, in accordance with which a provision for 50% increase in the live load will increase the cost of an ordinary 100 ft. span only about 10%. It is on this basis that the commercial aspects of the provision recommended for increase in live load should be gauged. Mr. Purdon, in discussing provision for increase in live load, has cited a case in which he finds that the making of a provision for increase in loading on a radically different basis from that recommended in the paper at an increase of 50% over the original cost would not have been economical. No bridge can withstand any increase in loading unless sufficient material is provided to withstand it. It follows, therefore, that any old bridge which has stood the test of heavier loads than those for which it was designed, had some provision for increase in loading, whether its designer intended it or not. The main question raised by the paper in regard to provision for possible increase in live load, is whether in making provision for contingencies, one of which is the possibility of greater loads than those specified, the distribution of the metal shall be governed solely by the distribution of stress produced by the specified load, or whether it shall, to some extent, be in accordance with the radically different distribution resulting from a greater load. The test of the sufficiency of the provision will be the greater load. It, therefore, seems reasonable to consider the distribution of stress under the greater load in arranging the provision.

The speaker notes with interest and desire for further information Mr. Schaub's observation that the yield point in compression is sometimes as much as ten per cent. less than what it is in tension. The statement in the paper that the yield

points for structural steel in tension and compression do not differ greatly, is based on the assertions of other authors and the series of comparative tests made by Chas. A. Marshall and given in his paper on the "Compressive Strength of Steel and Iron," Trans. Am. Soc. C. E., Vol. XVII., Aug., 1887. In these tests the yield points fluctuated, of course, but they run very nearly the same for tension and compression and with a slight advantage in favor of compression.

As Mr. Schaub points out, the tests on columns with pin ends seem to justify a somewhat less reduction in allowed load, on account of length, than required by the formula given in the paper. The speaker prefers, however, to use tests on columns with pivoted ends as criteria. Friction on pins is potent in raising the results in tests, but is a poor reliance in practice, as it may be overcome by a little eccentricity or a slight jar.

Mr. Schaub suggests that column lengths should be limited to 120 times the radius of gyration. The recommendation is conservative and doubtless has the support of many engineers. The speaker will not strenuously oppose it, although he believes that in specifying a formula which reduces the allowed load to zero at a length of 150 radii, he has made sufficient safeguard against slenderness.

Mr. Schaub's method of proportioning lattice bars is logically derived for columns with pin ends and is an important contribution to a subject which has needed and is at present receiving thoughtful consideration. The speaker's own views on this subject were recently presented to the Structural Section of this Society,* and he has nothing to add at this time except to question whether it is necessary, as Mr. Schaub suggests, to make the lattice bars three times as strong as the body of the member, in the case of long or moderately long columns.

The formula for impact to which Mr. Robinson refers as having been recommended by the speaker some years ago, is

—Impact$=L\dfrac{L}{L+D}$, in which L is the live and D the dead load stress. This formula did not have its origin in any theory of

* See page 607 f.

impact, instead it is an empirical one devised for practical use in designing bridges and was derived by arbitrarily modifying an existing formula to bring results in accord with its author's judgment. The formula of which it is a modification is:

Addition to Live Load Stress$=L\dfrac{L+D}{L+2D}$, and this parent formula was derived directly from Prof. Cain's modification of the Lannhardt formula by first substituting a constant allowed unit stress, in place of one varying with the relations between the maximum and minimum stresses, and then determining what addition would have to be made to the stresses in the members to bring precisely the same sectional areas, number of rivets, etc. That the formula Impact$=L\dfrac{L}{L+D}$, when used in designing new railway bridges, gives results fairly close to those given by Mr. C. C. Schneider's impact formula has long been known by the speaker, and the fact was recently established by numerous comparisons by the committee appointed by the Am. Ry. Eng. and M. of W. Ass'n. to prepare their standard specifications. There is a good reason for this similarity: Theoretically, the weights of beams or girders used under similar conditions and duly proportioned for their spans and maximum loads, will be proportional to the maximum load times the span. In the conditions of practice the coefficient which expresses the relation which the weight bears to the load times the span will vary greatly, nevertheless a rough approximation of the dead weight of an ordinary railway bridge can be obtained by taking $\frac{1}{300}$ of the live load (in pounds) for which it was designed and multiplying it by the length of span (in feet); that is roughly $D=\dfrac{L+\text{ Span}}{300}$. Sub-

stituting this value of D in the formula in question gives Im-

pact $= L \dfrac{L}{L + \dfrac{L \times \text{Span}}{300}}$ which reduces to, Impact $= L \dfrac{300}{300 + \text{Span in feet}}$

which is Schneider's formula. During the twelve years which have intervened between the promulgation of old formula and the presentation of the paper under consideration, the speaker's opinion as to the amounts which should be added for impact in designing new bridges has undergone some change, though not a radical one. This is entirely natural, as during that time the data on the subject has been increased by Prof. Turneaure's paper giving 359 tests and by the summary of some 2000 tests given in the report of the Impact Committee to the Am. Ry. Eng. and M. of W. Ass'n. The results of these tests, together with those made by Prof. Robinson, are shown in the diagram, on page 359, and the lines which bound the field in which they lie, indicate the formulas recommended.

The comparison of the various tests and the rules deduced therefrom are on the basis of the loaded length of span, instead of the relation of live to dead load, for two reasons: First, the data is not in good shape to be compared in accordance with the relation of live to dead load; second, although this relation is mainly dependent on the length of span, and therefore might serve in the comparisons and in the formulas, in place of the length of span, it is also dependent on other conditions, some of which, as shown by analysis, will actually modify the ratio of live to dead load in one way and the percentage of impact in another. This will be shown in the course of the discussion.

It is very gratifying to learn that these formulas appear to Prof. Turneaure to be a reasonable deduction from the available data, and to know that the available data will soon be enriched by the numerous tests now being made by him and his assistants. If these tests when added to the field enlarge its boundaries, a new "guess" (borrowing the word from Mr. Robinson) will be in order. In the meantime a "guess" based

on the data already available may be of some use in designing bridges, and discussion of the principles involved may aid those who are trying to discover the laws of impact, by actual tests.

In the trusses of long spans the maximum dynamic effect of the live load, which for brevity but not with strict accuracy may be termed "impact," is due to accumulative vibration. In the trusses of long spans, therefore, it seems reasonable to suppose, as stated by Prof. Turneaure, that an increase in dead load, other things being equal, will reduce the impact, but unless the increase is very great its influence will probably be of minor consideration as compared with the other conditions which determine vibration, and it is not apparent in the tests cited. For this reason the speaker does not recommend a reduction in the percentage for impact for which the truss members of long spans should be designed until a loaded length of 500 ft. is exceeded.

For short spans the maximum impact is not an accumulation of successive dynamic impulses but is the immediate excessive effect of a single encounter with a rapidly moving load as compared with the same load statically applied. Primarily this excessive effect is not the result of a blow, but is simply an increase in pressure resulting from the centrifugal action of the imperfectly balanced locomotive driving wheels, and its amount depends on the speed and the distribution of the moving parts.

It is possible, however, that at times the loads may strike or have the effect of a blow and it is in such a case, if at all, that the dead load will be of benefit in reducing impact on short spans. Prof. Turneaure has ably discussed this phase of the question. He has shown that in such a case the direct influence of an increase in dead load is to reduce impact, but that when the dead load, by being added to the section of the girder increases its stiffness, it indirectly increases the impact. A study of table No. 6 shows that the direct effect is not very great but that the indirect effect may be considerable. Another consideration may have attention to advantage. If the falling load is increased and the dead load remains stationary, the

percentage of impact will *decrease*. For instance, if in case 3 in table 6 the falling load is *increased* from one to two tons other conditions remaining the same, the percentage of impact will *decrease* from 386 to 295. This is one of the reasons why the speaker not only abandoned the formula Impact

$$=L\frac{L}{L+D},$$

but decided not to use any similar relation of live to dead load in devising the rules given in the paper, as the abandoned formula indicates an *increase* in percentage of impact with an *increase* in live load.

Attention has been called to the fact that in the paper and its discussion a distinction has been made between the effects of impact on long and short spans and it has been asked where the line between them is drawn. From an examination of the tests on which the paper is based, the dividing line appears to lie between 100 and 125 feet.

In the discussion of the recommendation in the paper that provision should be made for a possible increase of 50 per cent. in the live load, the question has been raised whether such an increase is possible with the present clearances, and the further question has come up whether the pressures on the soil of ordinary country under present conditions are not somewhere near its limit of resistance. The resistance to pressure offered by the roadbed can be increased by improved distribution. During the last 25 years no increase has been made in the depth of ballast; and the size of ties, owing to the increasing scarcity of timber, has, if anything, decreased. The need for radical improvement in this regard is recognized by railroad engineers and they are giving the matter serious consideration. There has been attributed to railroad magnates, in the newspapers some contemplation of rebuilding railroads so as to admit of larger rolling stock, but the difficulties in the way of such an undertaking are so great that it is hardly worth while to consider this contingency in this connection further than to anticipate such improvements in the roadbed as will

make the clearances between the tracks and above the rails the controlling element in limiting the loads per lineal foot. The present clearances admit of some increase in the weight per foot of steam locomotives and loaded coal cars, though hardly 50 per cent, but the possibilities of electric locomotives in this direction have not yet been fathomed and the capacity of cars for ore and metal products could be increased more than 50 per cent, above the present limits without encroaching on the clearance lines. In considering the liability of any line to heavy ore traffic, the possibility of foreign importations should be considered.

The point has been made that the metallurgical side of the subject should receive some attention in a paper on and discussion regarding the proportioning of steel bridges. That it is a very important side of the subject everyone will concede, but in practice, under existing conditions, the designing engineers' choice in this regard is not great, unless he is designing an unusual structure involving a very large tonnage, such for instance as a bridge of a very long span. For such a structure, in which the dead weight is a large proportion of the entire load, the comparative lightness achieved by use of steel of great strength is a decided advantage, especially for tension members, and may more than offset the disadvantages of increased cost and more expensive workmanship. The advantage, however, cannot be gauged simply by specimen tests, as it is the strength after the steel has been forged, or punched, drilled and riveted that counts. For compression members there is also buckling to consider, the resistance to which requires body and stiffness rather than strength. For the ordinary run of structures, whatever may be the designing engineer's views as to the best composition for structural steel, the quantity required is so comparatively small that it is not practicable even at an increased cost to obtain a special composition, and even if it were possible to do so, it would, doubtless, give greater security and longer life to the structures to put the increase in cost into more metal of standard quality. There is great virtue in body and many structures could have more to advantage. Greater reliability and uniformity in the quality

and properties of structural steel rather than increase in strength is the improvement which bridge engineers would welcome. The subject, however, is one which calls for careful investigation by metallurgists rather than theorizing by bridge engineers. As the metallurgist establishes important facts the progressive manufacturer and watchful engineer can be relied on to take advantage of each proven advance, but for bridges and analogous structures, new processes and mixtures in the experimental stage should be avoided, no matter how rosy the claims or satisfactory the laboratory tests. The conservative bridge engineer will await the test of service in other lines involving less risk to life and property before pinning his faith to new kinds of steel. Especial caution is necessary in using unit stresses greater than would be safe in ordinary structural steel. Even if the engineer is satisfied that he can rely on the superior strength of some special kind, he must reckon with fact that such steel cannot be distinguished by simple observation from the ordinary variety, and that, unless the mills are making and the manufacturer using the special steel exclusively, there is a liability that some steel of ordinary quality will get mixed with it, in spite of the best intentions and reasonable care. If he succeeds in getting only the special steel, there is danger, as has been pointed out in the discussion, that in course of time the structure will come under the supervision of other engineers who will not know the quality of the steel, and who, in judging as to safety, will be obliged to assume that it is no better than ordinary. Any advance in the quality of structural steel, to be of much use to the bridge engineer in his ordinary practice, must be a general one and in the direction of greater reliability and uniformity.

The speaker regrets that there has been no discussion regarding the available strength of structural steel. If the arguments advanced in the paper against the Launhardt and similar formulas (which are based on an enhanced and variable elastic limit developed by overstraining) cannot be met, the use of these formulas should be abandoned. In fact, present opinion and practice among engineers tend very strongly to-

ward regarding the elastic limit, as shown by the yield point, as the available strength of structural steel.

For ordinary structural steel as it comes from the rolls the available strength can be taken, as shown in the paper, at about 55% of the ultimate strength. The six tests of eye-bars given in table No. 6, tend to support this ratio, but the number is altogether too small to serve as a basis for a general conclusion. The fact that eye-bars are annealed puts them in a different class from material as it comes from the rolls, as the steel is softened and some of the good effect of rolling is taken away. The difficulty of drawing a general conclusion regarding the strength of eye-bars is increased by variations in the process of annealing. For instance, it is well known that eye-bars which cool slowly will be softer and, therefore, have a lower elastic limit than those which cool more rapidly. Engineers who insist that eye-bars shall be cooled slowly should do so with the knowledge that the process will lower the elastic limit. The average of all the tests, some 570, of full sized eye-bars, made during the last few years at the Ambridge plant of the American Bridge Company, gives an elastic limit equal to 52½% of the ultimate strength, with variations above and below this percentage. It is, therefore, unwise to count on an elastic limit for eye-bars of more than 50% of the ultimate strength.

Before the Structural Section, November 5th, 1907.

Chairman Richard Khuen, Jr.,

In the Chair.

Proportioning of Lattice Bars.

The Chairman: Mr. H. S. Prichard has consented to open the discussion.

Mr. Prichard: The speaker has shown in a paper not yet ready for publication that the load which will cause the failure of a latticed column depends in part on the size and inclination of the lattice bars. This is true even under ideal conditions in which there is no bending under loads less than those which would cause failure.

With the imperfections in material, workmanship and erection, inevitable in practice, there will be some eccentricity and, therefore, bending moment in every column: insidious variations in the modulus of elasticity, unintentional discrepancies in sectional area, imperfect facing and boring of end connections and tilting out of line in erection will cause eccentric application of the load with regard to the column's true axis, and kinks or curves in the axis will be developed during fabrication.

Case 1—Columns with pivoted ends and free from intentional eccentricity or transverse loading.

For this case the maximum stresses in the lattice bars of columns of moderate length and longer will occur when the axis of the column has the maximum unintentional curvature and the loads are applied at both ends, with the maximum unintentional eccentricity, to the concave side of the axis. Under the action of the loads the curvature of the column will be increased by deflection and, if a line is drawn joining the points of application of the loads at opposite ends of the column, the distance at any cross section from the deflected axis to the said line will be the eccentricity at that cross-section. The bending

moments will be proportional to the eccentricities and the moment diagram will consist of two parts, as shown in figure 1; a rectangular portion, corresponding to the eccentric application of the load, and a curved portion, corresponding to the initial curvature plus the deflection.

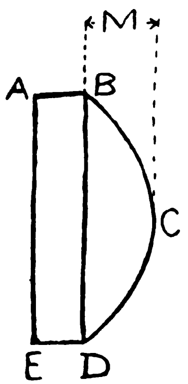


Fig. 1

Let M=the bending moment at the centre of the column due to curvature and deflection.

f =the corresponding stress in the extreme fibre; that is, the bending stress from initial curvature and deflection only.

l=the length of the column.

r =the radius of gyration.

I =the moment of inertia.

V=the distance from the nominal axis to the extreme fibre.

A=the cross sectional area of the column.

S_a=the average shear in the column at right angles to its axis.

S_m=the maximum shear in any panel.

C =the ratio of maximum to average shear.

$$S_m = CS_a \qquad (1)$$

The shear in any panel is equal to the difference between the bending moments at its ends divided by the length of the panel; hence the average shear in all the panels is equal to the difference between the moments at the centre and ends, divided by the half length of the column; that is,

$$S_a = \frac{2M}{l} \qquad (2)$$

$$S_m = \frac{2CM}{l} \qquad (3)$$

From the theory of flexure

$$M = \frac{If}{v} = \frac{A\,r^2 f}{v} \qquad (4)$$

Substituting this value of M in equation 3 gives

$$S_m = \frac{2cAr^2f}{vl} = \frac{r}{v} \times \frac{cfA}{l/r} \qquad (5)$$

The factor C varies with the form of the curve B. C. D. between the limits 2, for a column with eccentric application of the load, but no initial curvature or deflection, and $\frac{\pi^2}{2}$ (about 1.57) for a column with some deflection or initial curvature but without eccentric application of the load.

The value of "f" should be so chosen as to give the column a factor of safety. It is susceptible of determination by analysis, for any given assumptions as to initial eccentricity and curvature, and for the factor of safety desired, but the expression which gives its value in terms of these fundamental considerations is extremely complex and the crucial test of the sufficiency of the amounts assumed for eccentricity and initial curvature is the agreement of the results with the maximum values of "f" indicated by a large number of experiments. Such being the case theory is of more use in determining the law of variation; that is, in finding the relative values of "f" for varying lengths, than it is in establishing the maximum value. The speaker has found by analysis that, for the end conditions assumed the value of the expression $\frac{f}{l/r}$ and consequently the shear will increase, as the ratio of l to r increases, from zero at zero length to a maximum at a ratio of from 100 to 140 (according to the assumptions) after which it will decrease as the ratio increases. It will not do to follow this law too closely, as a difference in end conditions will alter the length at which the maximum occurs, and for short columns an entirely different set of conditions will govern the size of the lattice bars.

Instead of attempting to vary the value of "f" in accordance with theoretical considerations, its value may be approximately deduced from some of the numerous column for-

mulas in use. Of these formulas the speaker knows of none that lends itself more readily to the development of a simple and satisfactory rule for lattice bars than $p=16000-70\frac{l}{r}$, given in the Am. Ry. Eng. and M. of W. Ass'n. specifications. In this formula the expression $70\frac{l}{r}$ represents the allowance, in pounds per square inch, for bending stresses. Substituting this value for "f", and 2 for C, in equation 5 gives

$$S_m = 280\, A\, \frac{r}{v} \qquad (6)$$

For columns composed of two channels with their flanges turned out, r/v can be taken as $\frac{5}{7}$ without material error, which gives

$$S_m = 200\, A \qquad (7)$$

The results of equations 6 and 7 are, of course, in pounds. The combined stresses, in pounds, of all the lattice on both sides of the column in one panel, corresponding with the shear in equation 7; is, for 45° lattice, $283A$; for 60° lattice, $231A$.

For the conditions assumed the stresses in the lattice bars decrease from the ends toward the centre of the column. The lattice would, of course, be proportioned alike, and as the end panels have batten plates the stresses calculated by the foregoing rules will be somewhat excessive even for the end lattice. Further, the real value of "C," for the conditions assumed, is nearer 1.57 than 2, which further shows that the calculated stresses will be somewhat excessive for the said assumed conditions; that is, the rules are on the side of safety.

The foregoing rules are developed on the assumption that the loads at the opposite ends of the column are applied with equal eccentricities and to the same side of the axis. If instead they are applied so as to form a couple with a leverage

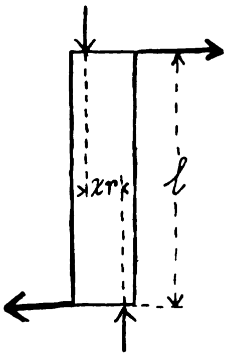


Fig. 2

xr, as in figure 2, then; *first*, if the column is very short, the load which the column will safely sustain will be very little reduced on account of column length; therefore, for determining the stresses in the lattice, it can be taken as $15000A$ in pounds; *second*, the initial curvature and deflection will be so small that they can be neglected or rather provided for by assuming xr a trifle larger than otherwise; *third*, the shear in the column will be constant from end to end and the equation giving the maximum shear in pounds will be

$$S_m = \frac{15000\,A\,x\,r}{l} = \frac{15000\,A\,x}{l\,/\,r} \qquad (8)$$

It is hardly possible that l/r will be less than 15 in practice, for which value, if S_m is $200A$, as in equation 7, x will equal $\frac{1}{5}$. As it is not reasonable to assume an unintentional eccentricity in the application of the loads greater than $\frac{1}{5}r$, nor a length shorter than 15 radii. $200A$ should be a safe amount to assume for the shear for lengths of column in use in practice.

Case 2—Columns with fixed, partly fixed and flat ends, and free from intentional eccentricity or transverse loading.

An ideal column with fixed ends would have points of contrary flexure distant from each end $\frac{1}{4}l$ and at the moment when the stress in the extreme fibre reached the elastic limit would have moments and shears exactly equal to a column with pivoted ends of half its length. (As a matter of fact, if the elastic limit was 40,000 lbs. the greatest shear at the moment when the elastic limit was reached would be about $570A\ r/v$ and would occur for pivoted ends when $l/r=146$ about, and for fixed ends when $l/r=292$ about.) Under the conditions of practice, except for very short col-

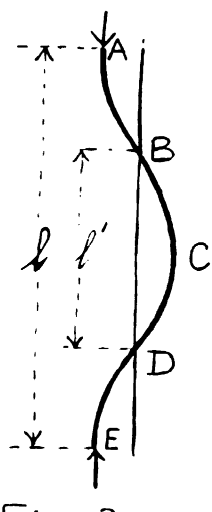


Fig. 3

umns, the moments, shears and strength of a column with fixed, partly fixed or flat ends is approximately the same as for a similar column with pivoted ends of a length of l', l' being the distance between the points of contrary flexure of the column. If l' is substituted for l in equation 5 and in the Am. Ry. Eng. and M. of W. Ass'n. formula for strength of columns, it will bring precisely the same value for S_m in equation 6, hence, the rules for lattice bars developed for pivoted ends will be safe for columns with fixed, partly fixed or flat ends, except for very short columns with flat or abutting ends, and posts to which floor beams connect.

The stresses to which the lattice bars of columns with imperfect butt joints are liable was discussed in "Engineering News" of October 3rd, 1907. Equation 35, given therein, indicates the stresses when the cross-sectional area of the lattice bars is known. For the purpose of designing new short columns with properly proportioned lattice it may be assumed in advance that the stress per square inch of gross section of lattice bars will be about 10,000 pounds, that the modulus of elasticity is 29,000,000 pounds and that the tangent of the angles "*a*" (that is, the equal and opposite angles made by the abutting faces at the ends of the middle column of a line of three equal and symmetrical columns) is 0.003. Substituting these values in the said equation 35 (Eng. News, Oct. 3rd, '07,) and reducing gives

For 45° lattice

$$S_m = \frac{238000\,A}{l^2/r^2} \qquad \text{(9)}$$

For 60° lattice

$$S_m = \frac{216000\,A}{l^2/r^2} \qquad \text{(10)}$$

The combined stress in the lattice bars on both sides of the column in one panel, for 45° lattice is $\dfrac{336000A}{l^2/r^2}$ and for 60° lattice $\dfrac{249000A}{l^2/r^2}$.

These equations indicate very high stresses as possible in the lattice bars, and equation 19 (in the article referred to) as possible in the channels, when l/r is very small; a fact which makes it advisable to avoid very short columns with abutting ends.

Case 3—Columns with intentional eccentricity or transverse loading, or with secondary stresses from the deformation of connecting members; for instance, the secondary stresses in posts to which floor beams connect.

Let p = the mean stress per square inch allowed in a column and A_1 the cross sectional area required for a column, with the same length and radius of gyration, as in case 3, but without any intentional eccentricity or transverse loading or secondary stresses from connecting members.

S_2 = the additional shear from intentional eccentricity, etc.

$$S_m = 280 A_1 \frac{r}{v} + \frac{16000 S_2}{p} \quad \text{(11)}$$

This equation is only approximate and should not be used when it gives smaller values than equations 6, 9 or 10.

The additional shear from eccentricity, etc., is increased in equation 11 to allow for the uncalculated increase in the shear resulting from the deflection of the column.

Mr. Thos. H. Johnson: While I did not follow Mr. Prichard very closely to see the manner in which he arrives at his result, I am very much gratified to see that he reaches one feature, that is entirely in accord with some investigations of my own along that line, and that is that the shear on the lattice bars bears a constant relation to the area of the section.

Willis Whited: Mr. Prichard has gone into this very fully and very carefully. There are a few practical points, though, that I think should be considered in designing compression members. Much depends on the quality of the workmanship the engineer is liable to get on the work, and it is well in de-

signing a compression member to know as accurately as possible what quality of workmanship can be depended on, both in the shop and in the field. Open joints are frequently due to carelessness or inaccuracy in lining up columns where one rests on top of another and they become quite considerable sometimes in buildings. In bridges they should not be so bad, but they are liable to be sometimes. That is a thing that should be carefully looked into and I am inclined to think that it is practicable for an engineer to ascertain pretty closely how accurate is the workmanship he can expect and then make his specifications in such a way as to call for that degree of accuracy and then insist on getting it.

For instance, if the engineer finds from experience that it is practicable to get a column straight within ½ in. he can specify that degree of accuracy and any member that shows a greater degree of imperfection than that can be thrown out or fixed before it leaves the shop. The same or a similar rule to apply in the field in case a piece is accidentally injured and also to injured members of old structures. The dimensions of the lacing will have weight in deciding what to do with a compression member of an old structure that has met with an accident.

Another point that is of considerable importance, and concerning which, so far as I know, there is very little information extant, is what is the greatest possible variation in the modulii of elasticity of different pieces of steel used in the same compression member. The eccentricity of the stress due to open joints in a compression member is a function of the modulus of elasticity of the member. If the modulus is uniform for the whole section one result is obtained, but if the modulus is considerably different on one side from what it is on the other, a different result will be obtained. I think it would be worth while to make a thorough investigation of this matter.

The strength of the splices has an important bearing on the effect of open joints in compression members. If they are fully spliced, open joints need not be considered, but to fully splice a compression member is often difficult or expensive, and in the case of chords or posts having more than two webs,

it is impracticable as a rule. In the majority of cases, however, it is doubtless as well to consider the splices as an additional security.

Mr. Johnson: In reference to Mr. Whited's remarks about the variation that we are liable to get in the modulus of elasticity of material. Some years ago, in the course of our bridge work on the line that I am connected with, we made some tests of full size columns, quite a number of them at different times, and in connection with that we made specimen tests of the material of which the column was built, determining the modulus of elasticity, as one of the elements in that group of tests. It is some time since I saw them, but if I remember the figures correctly, the modulus of elasticity varied all the way from 24,000,000 to 32,000,000, some such a range as that.

Speaking of those tests, from full size members, there was one feature developed that seems to be strictly appropriate to this discussion, and that is the behavior of latticed members. In the case of unlatticed members (I have particularly in mind a column of the Z bar construction) those columns deflected in the press uniformly from end to end, and on being released from the press there was a permanent set in about the middle third of the length, the two ends recovering their form and being tangent to the curve of the middle third. But with the lattice members, they failed, in every instance, by buckling between the lattice points.

Referring particularly to the ordinary top cord section with a plate on top and lattice below, the form of failure in each instance was that the horizontal leg of the bottom angle bent upward and the whole angle buckled inward between two hitches of the lattice bars. That seems to indicate that in estimating the capacity of a top cord section the area of that horizontal leg of the angle should not be given the full value that you give to equal areas of the rest of the section.

The Chairman: If I remember right those experiments gave you very low results in the stress per square inch.

Mr. Johnson: In unlatticed sections, such as the Z bar column, the results conformed very closely to the formula. In all of the latticed sections the results ranged from 70 to 90

per cent. of the results computed by the formula. In a few cases which failed in the end detail, the results were still lower, but failure in these cases was independent of their behavior as columns.

Mr. Whited: Speaking of the buckling of the outstanding leg of the angle of the chord, I think it is a question that depends a good deal on the dimensions of the angle. That is, if the outstanding leg of the angle is thin and wide the lacing should be closer and heavier. I think in designing compression members it is a good plan to make the thickness of the outstanding leg of the angle or channel a function of its width, and not make it too thin.

Speaking of the wide difference between the moduli of elasticity of different specimens of steel, I never supposed it was so great as in the cases Mr. Johnson mentions.

Mr. Prichard: I wish to emphasize the fact when a column is intentionally loaded eccentrically or with a transverse force, the shear resulting from that intentional eccentricity or transverse force should be added to the amount recommended to cover the unintentional eccentricity.

The Chairman: Do you include your tie plates at the ends in that?

Mr. Prichard: Tie plates at the end take the place of lattice. In a very short column the stress in the lattice bars may be nearly uniform throughout, but in most cases it will be different in different parts of the column, especially in long or moderately long columns; but I should not recommend making any difference in the size of lattice bars in any part of a column or reduction in size on account of the tie plates.

The Chairman: In short columns the tie plates run over a good portion of the length of the column.

Mr. Prichard: Yes, but the shear acting transversely to the axis of the column, will have to be carried through from one end to the other. If there are tie plates at each end and lattice bars in between, each panel of lattice bars will have to transfer the same shear as though there were no tie plates at the ends. The effect of changing from strong, stiff tie plates to weak lattice will be to produce local bending at the points

where the change takes place, thus making the stress at these points more severe than if the column was latticed throughout.

Mr. Edward Godfrey: The design of lattice bars, as also the design of columns, should be based upon the probable error in manufacture or in other words the probable imperfections that will develop in the building up of a compression member. Practice and theory have equal rights to be heard in formulating rules for the proportioning of members. A theory that starts out with a perfectly straight column and on that premise builds a rule of proportion is unreliable in just the degree that the column in its manufactured state deviates from perfection of alignment.

It was formerly thought that cast iron was an ideal material for columns, and that an ideal truss was one in which the top chords were of cast iron and the bottom chords of wrought iron. This was built on the premise that cast iron in short blocks is capable of resisting high compressive stresses. It is now realized that the inherent uncertainties in cast iron as a manufactured article greatly limit its usefulness as a column material. It is also realized by some that material for compression members must be capable of taking tension, whether or not the members are eccentrically loaded. Those who do not realize this are commended to a study of some recent disastrous failures of reinforced concrete buildings, where columns of plain concrete, with some longitudinal rods, have been the cause of great loss of life and property.

As long as the component parts of a column are perfectly straight the work of lattice bars is not much more than that of the fire company that sits ready to go to a fire when the alarm sounds. It would seem, then, that the proportioning of these bars is largely, if not entirely, a matter of guess or judgment; and, in fact, judgment is a good thing to go by in such a case, if it be good judgment. But judgment is apt to be swayed by individual interests. A good rule is more unvarying and will be productive of more uniform results. The more designing is reduced to rule, and the more inclusive the rules, the better will be the quality of the bulk of work turned out.

This means that professional common sense is only good in the absence of a good rule applicable to the case.

It is reasonable to assume that a compression member that varies from a truly straight line more than one-quarter of one per cent. of its length would be laid aside by an inspector as imperfect and needing straightening. It is probably close to the truth that deviations from a straight line not much less than this will pass undetected or will be accepted as commercially perfect. In a 10-foot member this would be $\frac{5}{16}$ in.; in a 40-ft. member $1\frac{1}{4}$ in.; in a 60-ft. member, the scapegoat of the Quebec bridge, $1\frac{13}{16}$ in. The observed deflection of the much-talked-of chord member *L* 9 was but little over one-quarter of one per cent. of the length. If this member had anything to do with the failure of that structure, it must, like Sampson, have received added strength in its expiring moments to lift the bridge and tilt it over to the right, though the member itself was in the left-hand truss. We have been recently told that the cantilever arm is now 50 feet to the right of its original position. It is scarcely possible to account for this one fact in any other way than to conclude that the top-heavy traveler tilted over to the right. This would account for the entire failure as well.

But, while I believe that chord member *L* 9 had nothing to do with the failure, I believe that a study of these chord members entirely apart from the failure, reveals the fact that they are weak. Stronger lattice, however, would not make up the deficiency, unless there were intermediate planes of lattice bars. We ought not to take four plate girders and expect them to act as a compression member, with nothing to unite them but top and bottom lacing. It is idle to figure heavy stresses in lacing angles in a member so deep as these chord members, since so much of the sectional area is remote from the planes of the lattice. The webs would buckle before imparting lateral force to the distant flanges. Longitudinal webs, or longitudinal stiffening angles, with extra systems of lattice bars and tie plates are the rational solution of the rigidity of a member having such deep webs. Such members are in a class by themselves.

The ordinary compression member has a large part of its area in the flanges or close to the plane of the lattice. For such members a plane of lattice in each flange, or a single plane in the middle in the case of I-shaped members, can be calculated as a lattice truss.

Taking the limit of the allowed deviation of a compression member from a straight line as one-quarter of one per cent. of its length and assuming that the curve is a parabola, the direction of the shaft at ends will be such that it would cut a point one-half of one per cent. from the centre line at the middle of the length of the member. Or if the member were curved with a sharp curve at quarter points and had the same deviation from a straight line, the direction of the shaft near the ends would be the same. It is a simple matter to show that such a member will have a shear near the ends just one per cent. of the total stress. The shear diminishes to zero at the middle of the length of the member. This shear is taken by the lacing. A rule for the proportion of a lattice system would be this: Make the system capable of taking a shear equal to one per cent. of the total stress on the member.

Such a rule would be troublesome for ordinary work, as it would result in an assortment of different sized bars, where now standard bars are generally used.

Taking the commonly used standard bars and maintaining a distance centre to centre of end rivets not to exceed 40 times the thickness, we have for the safe compressive strength of the several sizes the following (at $10{,}000-40l \div r$ per sq. in.).

$1\frac{3}{4} \times \frac{1}{4}$—1950 (1- $\frac{5}{8}$ in. rivet).
2 $\times \frac{1}{4}$—2230 (1- $\frac{5}{8}$ in. or $\frac{3}{4}$ in. rivet).
2 $\times \frac{5}{16}$—2790 (1- $\frac{3}{4}$ in. rivet).
$2\frac{1}{4} \times \frac{5}{16}$—3140 (1- $\frac{3}{4}$ in. rivet).
$2\frac{1}{2} \times \frac{3}{8}$—4180 (1- $\frac{7}{8}$ in. rivet).
$2\frac{1}{2} \times \frac{1}{2}$—5580 (1- $\frac{7}{8}$ in. rivet, @ 7500=4510).
3 $\times \frac{1}{2}$—6690

The compressive strength of a lattice bar governs rather than the tensile strength.

It is to be observed that the compressive strength of these various bars is about equal to the shearing value of rivets that conform to the various bars.

If the inclination of the bar be 60 degrees with the axis of the member, the allowed shear corresponding to the strength of the several bars will be found by dividing by 1.155. By making this division and multiplying by 100 we find that a single plane of lattice bars 1¾ in. × ¼ in. would take the shear of a member having a stress of 225,000 lbs. and a plane of bars 3 in. × ½ would take the shear for 773,000 lbs. of direct stress.

There is, of course, the possibility of some of the bars being bent and having their strength greatly impaired. In large members there will be two to four systems of lattice bars. But there is margin enough shown in this exhibit to make it clear that the common standards for lattice bars are quite sufficient for all ordinary members and to indicate that the size of bar should be selected on the basis of conformity to the size of member rather than any calculation of its stress.

For very heavy members calculation of the stress in the lattice bars would be useful, as these stresses would then be of sufficient magnitude to be out of the "nominal" class.

In members about four feet deep or more I believe there should be a transverse web in addition to the lattice system, in the flanges. A longitudinal stiffening angle and stiffeners perpendicular to flanges at intervals would answer the same purpose, if the flange lattice systems were extra heavy.

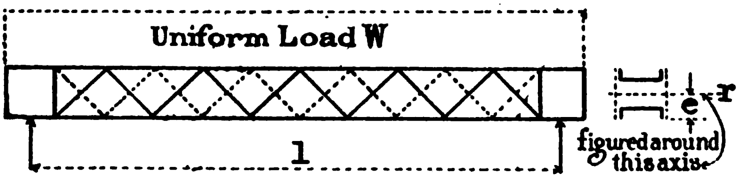
The Chairman: I received a week or so ago a formula that was worked out by Mr. Albert Reichmann, of Chicago, which corresponds very exactly with what Mr. Prichard has worked out.

In compression formula (M. of W. Specs.).

$$\text{U. S.} = 16000 - 70\frac{l}{r}$$

The term $70\frac{l}{r}$ represents the deduction that must be made in

the unit stress to provide for the bending, induced by the direct stress. This bending may be assumed to have been produced by a uniformly distributed load W, the max. shear of which shall be taken up by the lacing, as indicated in sketch:



The amount of W can be found then by considering that it must produce a bending unit stress of $70 \frac{l}{r}$. That is expressed by:

$$\frac{Wl}{8} = \frac{I}{e} \left(70 \frac{l}{r}\right)$$

Where I is the moment of inertia of the section of the post around the axis shown in sketch and e the distance to the extreme fibre. Now $I = Ar^2$, where A is gross area of section, and hence above equation reduces to

$$\frac{W}{8} = 70 \frac{Ar}{e} \text{ or } W = 560 \frac{Ar}{e}$$

The lace bars at the end have each a shear of ¼ W, hence the shear is

$$S = 140 \frac{Ar}{e} \sec \alpha.$$

and the stress, compression in one and tension in the other is

$$\text{For } 60° \text{ lacing } \sec \alpha = \frac{2}{3} \sqrt{3} = 1.15$$

It seems to me that such formula as that would be a good guide where you get to sections that are unusually large. In small ones, like a 200-ft. span with 30 or 60 square inches, with 24 in. cord, you do not need a guide of that kind very much. When you get something larger it gives you something to base your judgment on. In this connection if you will read Mr. Johnson's article in the Engineering News of September 25th of this year, he has worked out something very similar to this on a similar line of reasoning, and it seems to me engineers all over the country are getting down to something of that kind. I would like an expression of opinion from others here as to the advisability of using something of that kind to base your judgment on where you have sections of unusual size.

Mr. Sparhawk (non-member) read extracts from various specifications on the size of lattice bars, etc.

Mr. Whited: If the combined intellect of the engineering profession cannot evolve a reasonably scientific method of designing lattice bars, they had better shut up shop.

Mr. Godfrey: Mr. Prichard himself said that this formula is more or less of a guess.

Mr. Prichard: The formula is empirical, but it can hardly be called a guess. If the conditions for any given case were exactly known, the stresses could be rigidly determined, but formulae for columns under the conditions which exist in practice cannot be rigid, because there are imperfections in material, workmanship, etc., which make a bending moment in a column in which there would not have been any if the material and workmanship had been perfect.

There are two ways of arriving at a column formula; one is to decide what imperfections are reasonably possible and then develop a formula therefrom; the other is to establish a formula empirically from the results of tests; both ways of investigating the problem have produced formulas which give fairly close results. The column formula given in the specifications of the Am. Ry. Eng. and M. of W. Ass'n., though empirical, is safe and fairly economical. It lends itself readily to

the development of a formula for lattice bars which, as I have endeavored to show, is safe and fairly satisfactory for a large range of lengths and conditions.

The Chairman: It would appear to me that the matter of whether this underlying formula is a guess or not is immaterial. If you have to guess, be consistent. If you have to guess at the main section, follow out the same line of guessing when you get to the lattice bars.

Mr. E. W. Pittman: The straight line formula coincides almost exactly with the rigid column formula within the limits of shear for ordinary columns.

It might be interesting to know that about ten or twelve years ago a lattice bar formula was given by Prof. J. B. Johnson and it was incorporated in his "Modern Frame Structures," page 225, first edition. He used the straight line formula and took that portion of it which represents the fibre stress due to bending moment in making up his formula for lattice bars.

Mr. Jno. A. McEwen: I notice by looking over Mr. Waddell's specifications that he seems to have widely covered the whole subject by making a general requirement that columns having a bending moment have webs at right angles to the line of the bending moment. Since everybody seems to be of the opinion that every column has a bending moment it is necessary to have webs in all cases. I think it is a pretty good thing to keep away from lattice bars as far as you can.

There is another point Mr. Khuen touched on and that is the putting in of large tie plates. It seems to me that has some good points about it, to stiffen up and distribute the stress over the body of the column. Another thing in particular in heavy work is putting in a diaphragm on a web in compression members. It seems to me that adds a great deal to the stiffness of the column; not from a theoretical standpoint possibly, but it distributes the load and no doubt makes up the unevenness in quality of material.

The Chairman: Before adjourning the Chair would announce that this same subject will be discussed by the Western Society of Engineers at Chicago and it might be interesting to get their proceedings and see what conclusions they come to.

Vol. XXIII. JANUARY, 1908 No. 10

PROCEEDINGS

of the

Engineers' Society

of

Western Pennsylvania

CONTENTS

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PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIII JANUARY, 1908 No. 10

December 17, 1907.

President S. M. Kintner
In the Chair.

History of Glass Making.

BY GEO. A. MACBETH.*
Member.

GENTLEMEN: I must confess to a hesitancy in addressing the Engineering Society. While I have not been in attendance at the meetings for a long time, I notice from the Proceedings that your subjects have involved considerable research and work, and as it is a learned society, I feel it incumbent on me to be very careful in statement. I feel that I am treading on critical ground, but this is not a critical audience, I trust.

I was asked the other day where the word glass came from, and I did not know. I went to the library and found that we have adopted the name which was formerly given to amber. I decided some time ago that one who is in the manufacturing business possibly should look up the early history of what he is working with as a pleasant pastime, and I find it has brought me into the entire history of Egypt and the Phoenicians. And after searching through all the books I could find, I am greatly impressed with the general looseness of statement and unre-

* President Macbeth & Evans Glass Co.

liability of many of them, not only in the historical branch of it, but in the technical also. And I must say that if the historical part is as bad as the technical, the books are not worth much more than the illustrations.

DISCOVERY OF GLASS IN EGYPT.

Notwithstanding the universal use and importance of the substance we know as glass, the source of its discovery and invention has remained a matter of mystery and conjecture until the most modern times. The publication of the results of the excavations and discoveries of the last 25 years furnish a far better clue for a reasonable explanation of dating of this important substance than mere conjecture; and sufficient facts have been gathered to justify much more reliable conclusions than at any time previous. But even with the facts before us they can only be interpreted in the light of more correct chemical knowledge and a better acquaintance with the manipulation of the material than most of the writers who have written on the subject are possessed of.

All evidence tends to the undeniable first appearance of glass in Egypt. In no place else in all the world has its prior use been discovered, either in the form of a glaze, a paste, or a true glass.

We can imagine the easy invention or discovery of making a cup out of mud or clay, which when dried would hold liquid; also of the further burning of this cup, by which its hardness and usefulness as a containant of liquid was greatly increased. This is a common utensil the world over and more than likely was discovered by other nations besides the Egyptians. But the discovery or invention of glazing was quite a different matter, as it is closely related to the smelting of copper ore, and would not be discovered by a nation unfamiliar with this art. This, however, the Egyptians practiced at a very early period. Nowhere else in the world do we find prior to 3000-4000 B. C. remains of copper glass or glaze; at which time, however, the Egyptians were mining and smelting cop-

per at mines on the Sinaitic peninsula,[1] notwithstanding the fact that in historic times Egypt was not known as a timbered country, nor a country where fires were used sufficient to fuse a glass.

COPPER GLAZE ON POTTERY.

From the very first dawn of history, the flint arrow-head was in evidence, and next to this pottery, unglazed but ornamented. Speaking in a general way, copper is the next thing in prehistoric times, flints being used side by side with copper tools from the fourth to the twelfth dynasties; but not until a long time after the appearance of copper does glazed pottery make its appearance, being preceded by glazed stone. All of this early glazing indicates by its color, which is blue or bluish green, in the case of some more exposed pieces darker green, the unmistakable presence of copper, and analysis shows a good percentage of this metal. Considering the composition of this glaze, as well as the composition and color of the oldest piece of glass, we see how closely the glazing of pottery and the discovery of glass are associated with the smelting of copper and how this association centres around the mines of the Sinaitic peninsula, where copper mines were worked from three to four thousand years B. C. This glaze may be considered the first glass and this first glass, it is to be noted, was a colored glass, long before the discovery of a clear, transparent glass. The operation of the copper mines at Sinai must have been quite extensive for the times, for Lepsias states that he examined and walked over a bed composed entirely of copper slag, 250 paces long and some 30 to 120 paces wide, and several feet in depth. The operation of these mines were carried on by the builders of the tombs of Beni Hasson, the dating of the tombs being about the twelfth dynasty, or about 2500 years B. C.

If we place ourselves in the position of one who has never seen a piece of glass of any description, it does not require a great stretch of imagination to picture the curiosity which

1. Lepsias, "Egypt, Ethiopa and Sinai," p. 22.

would have been displayed at this discovery; a piece of slag, not so hard as agate or flint, but capable of being polished, and which could be cut as a seal, or made into a bead, both very important in the Egyptian customs and practices in all times. The number of scarabs and small images found, dating from somewhat before this period, and on for thousands of years, is most astonishing. They have been made out of various substances, but a piece of glass like copper slag, and a glass like mixture later, would have been a most admirable substance to use for this purpose, and undoubtedly it was so used.

BLOWN GLASS.

In one of the tombs of Beni Hasson is a picture of two men blowing into a fire through metal pipes or what may be reed pipes tipped with clay. These have been supposed to be glass blowers, and, if so, the date at which glass blowing was known in Egypt must be set back several hundred years. But, though accepted by archaeologists and scholars the world over, until within a comparatively recent period, doubt has been thrown upon the fact of their being glass blowers by Mr. Griffith, who is entitled to the greatest respect, and regarded as of the highest authority.[2]

For it seems from what we learn from another place in the same volume, that there are no remains of *blown* glass at that early period, which is undoubtedly correct. And since blown glass could not have been made without leaving some remains it does appear is if these men could not be blowing glass. Remains of glass are among the very oldest things we have, and until such are found of blown glass, we are obliged to doubt that these men are glass blowers. But one thing is evident, they are blowing into a fire, either to make it hotter, to melt metal or for some other reason, and no matter which, it gives us a hint as to how glass blowing was most likely discovered.

About 1300 B. C. we find the remains of a glass crucible

2. This illustration, which was shown at the meeting, can be found in "Egyptian Exploration Fund," Vol. IV., "Beni Hasson." The book is in the Carnegie Library, Pittsburgh.

or pot, being a shallow vessel some 12 inches in diameter, made of clay. We not only find the crucible itself but the glass of such form that it is clear it had been melted in a crucible.

Now, if the Egyptians were familiar with the use of the blow-pipe for increasing the heat of the fire for fusing metals, they would undoubtedly do the same thing for the fusing of copper slag, or copper slag mixed with alkali; indeed, we are not left to conjecture about this, copper slag that had been melted in a crucible being among the finds.

Now, having the molten glass in the crucible, we can easily see that if the blow-pipe, be it of reed or metal, should by accident or design happen to be dipped into the molten glass and then blown in, we have the discovery of blown glass; not an invention at all; perhaps, indeed, the mischievous trick of an idle boy, one of such who, in defiance of all rules, have made some of the greatest inventions of the world.

PIECING GLASS.

From the first appearance of glass-like copper slag at Beni Hasson or Thebes, at 2500 B. C., until the period of 1300 B. C., say a thousand years (a length of time which we can hardly appreciate), progress in the development of the art of making glass was very slow; but during all of this time the manipulation of melting various small pieces and making small articles and fusing them together into one piece was carried on, and the specimens as we find them in our museums show quite clearly the direction the development was taking.

About 1300 B. C., as has been stated, we find the remains of a clay crucible or pot, and samples of glass and copper slag which had evidently been melted or partly melted in it. And in addition, various forms of clay moulds, the first glass moulds found. These moulds are of clay with indentations of many shapes for making forms, some of them star-like, the glass being dipped from the crucible and put into the clay mould for the purpose of joining together pieces of different colors. The finds indicate the idea of pulling out the pieces fused together

like taffy. Thus we find pieces of glass in which the figure of a bird, say, passes through the piece from end to end, the various colors and forms being continuous, although often of microscopic proportions.

This has led to great astonishment on the part of the learned (!) ignorant of glass working. It has been extolled as a "lost art" to which modern civilization was unequal; but it is nevertheless very simple and is performed every day by the confectioner when he unites different colored candy together and draws it out, or when a single word or motto traverses the whole stick. The "secret" being simply that as the candy is pulled out all parts of the stick or figure diminish in size proportionally.[3]

GLASS MAKING BY THE PHOENICIANS.

Pliny gives a well-known account of the discovery of glass by Phoenician sailors who built a fire on the sand with which some soda was mixed.

Now this account is untenable, and we note that Pliny does not give it other than a story he had heard. On the other hand, it is not to be wondered at that such a relation should become current, considering that Egypt was not a timber-producing country, there being no occasion there for furnace fires, or fires other than for the most necessary domestic use; while Phoenicia was heavily timbered and its people, the great traders of the world at that period, were accustomed to the use of fires and became the glass makers of the world after the Egyptians.

From the copper glaze of the tombs of Beni Hasson to the making of a true glass occupied what to us would be a very long time, that is, about 1000 years. The mixture of alkali from the Natron lakes (in the vicinity of Alexandria) with a substance like copper slag, developed into nearly what we know as glass, the first pieces being altogether opaque, showing the insufficient heat and insufficient alkali or flux. The

3. Samples of glass of different colors, fused together and drawn out in this manner, were exhibited to the audience.

decomposition of pieces found is exactly what would happen to glass made this way. The Phoenicians at this period being almost the exclusive traders with the Egyptians, appropriated the art. And from this time forth glass marks the trend of commerce and the tracks of the first navigators of the then known world. Timber abounded in Phoenicia, as has been said; its people were accustomed to fires, and had besides a better knowledge of chemistry and more chemicals than any other people of antiquity. But, as Pliny states, a certain white earth obtained from Egypt, i. e. Natron (carbonate of soda), from the Natron lakes, was necessary to make glass at Sidon. The Phoenicians were also acquainted with the alkali carbonate of potash obtained from the ashes of sea weed.

IMITATION OF PRECIOUS STONES.

Much has been said regarding the imitation of agate and other stones. The glass-maker, accustomed to the making of colored glasses, knows full well the many and curious pieces, much resembling agate and many other stones he encounters by accident, and the first pieces of glass were more likely like agate than not;[4] their streaks of copper and iron earth or ore are not intentional, but incidental to the state of the art.

It is worthy of note that the reason for so many remains of glass-making being found, i. e., fragments of colored glass, in Egypt and Phoenicia is caused by the impossibility of fusing the various colored pieces again, and producing any certain color.

The art, however, was perfected by the Phoenician glass-makers and the remains of their glass show them masters of the art of blowing clear, uncolored, and colored glass; moulded, and made "off hand."

They were the first to put glass handles on glass vessels, and all of the glass found in Greece and Cyprus, which was formerly called Greek glass, is Phoenician. Examples of this can

4. Specimens of agate like glass—"glass house accidents"—were exhibited.

best be seen in the Jarvet collection in the Metropolitan Museum, and has been treated extensively by Froehner in his catalogue of this collection.

To treat particularly of the history of glass from this time forth would require volumes and time forbids entering into the history of the manufacture of it from this date to the present time, which would involve its manufacture by the Phoenicians and its spreading thence to the Netherlands, to France and England.

THE MYTH OF MALLEABLE GLASS.

Even at this late day it seems necessary to say something in regard to malleable glass, but the subject has been so well taken care of in a little book published about three hundred years ago, and now somewhat rare, that I quote liberally from this little publication of Neri,[3] for, strange to say, it contains most of the fundamentals regarding the chemistry and manipulation of glass and contains sound information for the glassmaker of today:

> "Concerning the malleability of glass, whereon the Chymists build the possibility of making their Elixir, take their weak foundation from Pliny, lib. 36, cap. 26. They report, saith he, that when Tiberius was Emperor, there was invented such a temperament of glass that it became flexible, and that the whole shop of the Artificer was demolished, lest the prices should be abated of the metals of brass, silver and gold, and this report was more common than certain. Now Pliny lived in the time of Vespasian, who was the third Emperor from Tiberius, so that it appears this report continued long. Many after him relate the same, though with some difference, Dion Cassius, lib. 57, thus: At that time when a very great Portico at Rome inclined to one side, a certain architect (whose name is unknown, because Caesar through envy forbid it to be registered), strangely set it upright, and so firmed the foundations on every side, that it became immovable. Tiberius, having paid him, banished him from the city, but he returning (as a supplicant) to the Prince, wittingly let fall a cup made of glass, and when it was broken remade it with his hands, hoping thereby to obtain pardon; but for this very thing he was commanded to be put to death. Isi-

3. The Art of Glass, by Antonia Neri. Translated from the Italian. London, 1662.

dorus affirms that the emperor in a chafe hurled it upon the pavement, which the artist took up, being battered, and folded like a vessel of brass; he then took a hammer out of his bosom and mended the glass, which being done, the emperor said to the artist, 'Doth anyone else know this way of making glass?' When he denied it with an oath, Caesar commanded his head to be cut off, lest this being known, gold should be esteemed as dirt, and the prices of all metals should be abated. And, indeed, if vessels of glass did not break they would be better than gold or silver. These three grave authors, Pancirollus and others follow, only telling it as a hear-say, but Mathesius, Goclenius, Valensis, Quatriami, Libavius, and all the tribe of the Chymists, assert it with great confidence, affirming that it was done by the virtue of the Elixir; but for all this confidence of theirs, Pliny only relates this story with a *ferunt*, they report, and with a *fama*, the report was, and thirdly, more common than certain, which thrice repetition of such like words, sufficiently argue his small belief of the story. It had been enough to have introduced this improbable relation the usual way with a *ferunt.* and hereby sufficiently have provided for his reputation, which, at most, proves only that some small credit was by some few given to it, but a disbelief in the wiser sort. For what can such words as these (they say such a thing, but the report is most uncertain), impart, but a diffidence in the relator? And 'twas but a fama, no naturalist, poet, nor historian deliver it, no record of the person, nor unusual punishment, which is strange, when their books abound with observations of whatsoever rarely happened. And is it probable that the Emperor himself should not lay up this glass as a secret in his choicest archives, and have transmitted it down to his successors, as a thing worth the keeping, being the first of that nature ever made in the world, and perhaps the last, the artist being put to death. And yet within a few years all this most rare invention and strange punishment vanish into a report only. All then was but vox populi and Romani too, nay, of the cruelty of a Nero, too, all which might easily keep up this fable. But why did Pliny then relate it? Surely to please and follow his genius, which was to commit to writing whatsoever was rare in art and nature, as his nephew in his epistles, and this present work witness. Now, on this account he might take occasion, in a thing perhaps he judged not impossible, to commend that present age (should after times produce any such effect) and so ascribe the invention thereof to his own nation. Besides 'twas but such a temperament of glass that rendered it flexible. And is it credible

that after ages should not light on it, especially in a thing so commonly practised, and where to so few, but two materials only are required. Or what means fame by the undervaluing of gold and silver? I confess I see no inconvenience to the Emperor, nor his gold and silver value, by this invention, but many ways advantage, nor any force of consequence in Caesar's words. But so much of Pliny's testimony. And what! shall the borrowers from him gain more reputation than the first relator gave it? Surely no, especially since they have made such a commentary on Plinys text, the words will not bear, and have with additionals moulded it into a formal relation, Pliny saith, "Ut flexible esset," that it might be flexible. Dion comments, the man remade a broken glass (one degree to malleability), but Isidorus completes it saying, with a hammer he mended it. Hereby you may see the degrees how this opinion came into the world, and by what strange piecings, variation and interpretations, it hath been fomented to make that seem credible to after ages, which Pliny relates as a vulgar tradition, adding thereto a censure of uncertainty, which the Chymists, to keep up the opinion of their omnipotent philosophers' stone, omit, and turn Pliny's flexibility into malleability, as if there were no difference betwixt flexible and malleable, whereas all bodies are in some degree or other flexible, though none but metals malleable. A green stick, Muscovie glass, and infinite other things will bow very much, whereon the hammer, notwithstanding, hath no effect as to dilatation and formation into thin plates, such as things called properly malleable have. And that glass is in some degree flexible of itself 'tis apparent, for fine crystal glasses made very thin and well annealed, will bear some small, yet visible, bending. And I have had tubes made twelve foot long and longer for the mercurial experiment, which being filled therewith would bend exceedingly; so that I am prone to think that if there were anything at all in this narrative of Pliny it might be this: That whereas their glass before this time was most brittle, as being made of saltpeter, and the art of annealing it (not mentioned by Pliny) unknown, and consequently must break with the smallest force. Now this artist might invent and show such glass as might accidentally bear a fall, or greater force, than what was formerly made, by making it of Kali, and superadding the way of annealing it, which might give occasion to fame, whereof Virgil, *parva metu primo, mox sese attollit in auras*, to add some circumstances, (which is most common with the vulgar), and so to form this story related by Pliny.

Now as to the possibility of making glass malleable, I find not one argument, besides this report, unless by the Chymists who prove it per Circulum, reasoning from their Elixir to glass, and from glass to the Elixir. And surely it were more feasible to make the one than the other, for in the making of the Elixir the production is *tale ens ex non tali ente*, there being no resistance and incapacity in the matter *ex qua*. But in glass quite otherwise, for it is of its own nature the most brittle thing in the world, and to make in malleable a quality quite contrary to its nature must be introduced. Besides diaphaneity is a property not communicated to anything malleable, and who would call that glass that were not transparent? As well may one name that gold which is not ponderous nor malleable, as that glass which is malleable and not transparent. Add hereunto that the nature of malleability consists in a close and throughout adhesion of parts to parts, and a capacity to the change of figure in the minutest parts, both which are inconsistent with the nature of glass. For the materials of glass, sand and salts, have such figures as seem incapable of such adhesion in every part one to another, for all salts have their determinate figure which they keep too, in their greatest solutions and actions of the fire upon them, unless a total destruction be wrought upon them, as many instances might evince, and that figure is various according to the salts. Saltpeter and all alcalizate salts are pointed, and by their pungency and caustickness seem to be made up of infinite sharp-pointed needles. And as for sand, the figure thereof is various, nay, infinite, as it appears in microscopes. Now how can any man imagine that such variety of figures in sand can so comply with the determinate figures of salt as to touch one another in *minimis*, which is necessary to make it malleable; whereas to make it glass it is enough that these two touch one another at certain points only, whereby such a union is formed, which is necessary to denominate glass, but wholly incompatible with malleability. And this union is that which makes in glass pores, from whence comes its diaphaneity as you have heard from Lucret. Besides something said before declares that they both remain the same in the compound they were before. I shall conclude this argument and say that I conceive that nothing but the Elixir will perform this effect, and that both of them will come into the world together."

GLASS MAKING BY MACHINERY.

I had something to say in regard to mould development, continued Mr. Macbeth. Strange to say, these pictures in this

book of 1611 show precisely the same tools we use today. Any accounts that I have possibly been able to discover previous to that time confirm the same thing. All books since that show the same tools, the same general corrugated moulds used from Ptolemaic times clear on down until probably within the last twelve or fifteen years.

The press might be said to be the first machine of consequence in regard to forming glass by machinery, and its use in this country has been very extensive, the best process and the best work being done here. Within the last ten or fifteen years blowing glass by machinery has arisen and it is now an important element in the manufacture, fairly revolutionizing the process.

The paste mould has been well known and accomplishes what we can hardly accomplish in other directions, but it took quite skilled labor to do it well. So it led finally to the invention of what we know as the Owen's blowing machine; the general principle of which is five paste moulds carried on a circular strap at least three-fourths of the circle. Then it comes to an incline and drops in water, for the purpose of cooling the moulds. Compressed air does the blowing, and whereas formerly we would pay a gatherer of glass for *gathering and blocking*, as it is called, (putting it in form to be introduced into the mould), as well as the blower, with the machine the blower in place of doing any blowing, just places the pipe in the machine perpendicularly, gives the merest little puff of air, and his work is done. And it is better done than any human being can do it, because it is self-centreing and we can blow articles of considerable length, 12 to 14 in., with almost absolutely uniform walls and sides. Hardly any of it is thick on one side and thin on the other. They are so uniform that I would be willing to take a contract for 100,000 on a stipulation that they would not vary over $\frac{1}{32}$ in. in diameter, 10 to 14 in. long.

I want to speak of one more machine, about which I do not know quite as much, having merely examined its operation; that is, the Owen's bottle machine. It is entirely auto-

matic, being a combination of pressing and blowing. It requires no glass blower at all. A man with an oil can and a monkey wrench can do all the work. It is fitted with five moulds, and just as they get over where the glass is, in their revolution, the receptacle gives a little curtsey and dips out just as much glass as needed. In that way it will turn out 16 beer bottles in a minute and work Saturdays and Sundays and holidays and all the time.

VARIOUS KINDS OF GLASS—THERMOMETER TUBES.

I think possibly you would be surprised to find out how many different kinds of glass we are forced to make. One of our factories is always making 25 to 30 different kinds right along. While we do not make them, I speak of it as an indication of some of the other operations—the making of thermometer tubes. It has brought up a whole chain of consequences. A thermometer tube ought to be allowed to season for one year at least. If filled with mercury and put into use when new, it shows variation according to the kind of glass, sometimes a very considerable variation. And what is worse, it shows a different variation at zero than at the boiling point. Then if it is brought up to the boiling point it does not go back exactly to where it was before.

My theory of glass that is made to withstand heat is to make it a good conductor of heat, for the reason that glass usually is a poor conductor, and if one end is heated it expands before the other can get hot and expand so it fractures. So to follow that out I make a glass that is a good conductor of heat. That so far as ordinary things go is right and good enough, but here comes these tests in thermometer tubes—and that is an unsolved problem as yet. Failing to indicate correct temperature might be a serious matter sometimes.

This has led to the search for a glass with a minimum of expansion and contraction; of unchangeableness, so to speak, so that if used for the purpose of indicating temperature it would probably not be out more than a small fraction of a degree.

A series of experiments which are not yet finished has been undertaken along this line, and it has led to the inquiry, how can we make glass with not so much of expansion and contraction?

ANNEALING.

Then annealing is an important thing in glass; in many things it is essential. I will leave the annealing of optical glass to an expert to tell you. An optical glass that is not well annealed is of no use, but with many other things it is getting to be almost as much of an essential as with optical glass.

GLASS FOR USE UNDER PRESSURE.

Then it appears that glass under pressure, like in a locomotive boiler, with 200 to 250 lbs. pressure, and hot water and steam, is soluble. If you put a pop bottle in such a boiler it will dissolve. It is really more soluble in cold water than you would think, for distilled water, pure water, attacks some glass as much as a strong alkali or an acid, and it shows in delicate tests for alkali. In glass that has to stand a pressure of 250 lbs. and hot water, that is quite a problem. We have been able to do some possibly as good things as have been done for this reason. We can actually fuse rock crystal. And what that means you may guess when I tell you that I have examined carefully sand that has been at a temperature of 2800 for two years without cessation, and after careful examination with a microscope with a 1-in. glass, I could not tell the difference between that and sand that was never used at all.

The angles were just as sharp. Now you can tell the difficulty of melting sand or rock crystal. We *can* melt it, but what is to be done when melted—it cools so quickly that it is difficult to get it in any form at all. The expense is very great and to get it into some forms is all but impossible. Then the necessary temperature of 4000 or over is apt to destroy the containing vessel and lose hours of melting. This is rather a

hazardous undertaking and the results are erratic, so that glass of that kind is necessarily expensive.

COLORED GLASS.

The other branches which we have been very successful in making in this country are the colored glasses. We lead the world far in the old machine, the press; across the water they have nothing comparable with it either in the grade of the glass or the matter of the finish.

The matter of the railway requirements in reds, greens and yellows to come within a certain compass of the spectrum has led to the making of new reds. Gold ruby is the most beautiful ruby red and corresponds probably the closest to the red of the spectrum, something like No. 40 carmine. But, strange to say, the other that borders between that and orange has the most luminosity. So that when it comes to using a signal at sea, ten miles away is a test for it. In that kind of work our chemists lead.

CASE HARDENED GLASS.

There is another kind of glass of which I would say a few words. There is such a thing as case hardened glass; a piece of glass heated to low redness, dropped in tallow at about 320*F*° comes out *case hardened.* Through the polariscope it will show all the colors of the spectrum, but just as soon as the case hardened surface is cut through it flies into a thousand pieces in all directions. The strain overcomes the tensile strength of the glass and an explosion is the end of it. It does very well in some things, but not in others.

The papers which have been read before learned societies and published, and tests made show there is not much difference in the tensile strength of the various kinds of glass. In glass making the chemist is all well enough, but his best efforts can be so defeated in the mechanical operation necessary, that they will be destroyed.

The President: I am sure you will all agree with me that we have listened to two very interesting papers.* I am glad also that we have here tonight a specialist on both these subjects, and I would ask Mr. Wadsworth to open the discussion.

Mr. F. L. O. Wadsworth: I really do not know on what line to start, the subject is so broad. The question of the manufacture of glass and of its applications is one that seems to me capable of greater development, and to present greater possibilities both to the engineer and to the scientist, than almost any other subject with which we are concerned in engineering practice today. As Mr. Macbeth aptly said we are doing things today in the glass business just as they did a thousand years ago. And we are doing them not because there are no better ways, but for the sole and simple reason that we have been doing them one way for so long that there is now an inertia that prevents change.

As I say, it is difficult to choose one branch of the subject that might best open discussion, but I would like to ask the chemists who are present to present their views as to what glass really is. I don't believe they have any established views. That will bring before you perhaps, very forcibly indeed, the fact that very little is known about glass. As far as I know—and the chemists will correct me if I am wrong—they do not even know to day what glass is, whether it is a chemical compound or simply a mixture.

The President: We would be glad to hear from Mr. Stutz on any points he may desire to make in connection with glass.

Mr. C. C. Stutz: The subject of how strong glass is and how much it will stand comes up quite often. There is not much available information in text books to enable one to give a proper answer in this respect, and it is for this reason that I bring up the subject.

The other day a show man came along with a little scheme for entertainment. His idea was to use two big plates of glass

* Dr. Brashear's paper on "Contributions of Glass to Our Knowledge of the Stellar Universe" will appear in a subsequent number of the Proceedings."

about 8x10 feet; place them parallel to each other at a distance of about 18 inches to 2 feet; fill the interval between them with water in which he was to place water plants and fishes, and behind this partition formed of these two plates it was his idea to place a structure representing a shipwreck, and, perhaps, have a little performance go on, giving the impression that all this was being done under water.

When it came to figuring the pressure which the water exerted on these two big plates, it was found that they would have to be so thick that they could only be produced at an enormous cost, and, of course, the scheme fell through.

This only shows how some people are under the impression that glass will stand a great deal of pressure, but such is not the case.

In dealing with the strength of glass, such for instance as a polished plate, there are one or two points I would have you bear in mind. In the first place, glass is not a substance that we can figure the strength of as we can a great many other things with which we are familiar. It varies greatly in itself. The strongest glass, as a rule, breaks into the greatest number of fragments. Comparing the strength of thin glass with thick, the former is relatively the stronger; this is a thing very often lost sight of. Then again as to the difference between rough plate and polished plate, we find polished plate the stronger. I attribute this to the fact that all these very fine surface hair cracks are polished out. These only go into the glass to a certain depth and when they are all or nearly all polished and ground off there is less chance for some of them to form the basis of a crack, and thereby the glass is increased in strength.

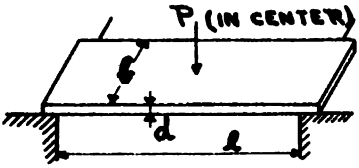
Tests have been made and some formulae have been arrived at. As was to be expected they show very irregular results as to the strength of glass. I here have an extract of those formulae and some of the figures. (*See table on next page.*)

The point is brought up in this connection of the annealing of glass and this is, of course, a very important point. We find there are two ways of annealing glass, one known as kiln

STRENGTH OF ROLLED GLASS

NOTES FROM WATERTOWN ARSENAL TESTS (1901)

TRANSVERSE TESTS



$$R = \frac{3Pl}{2bd^2}$$

$$P = \frac{2bd^2R}{3l}$$

R = MODULUS OF RUPTURE IN LBS. PER SQ. INCH.
P = LOAD IN LBS. (APPLIED IN CENTER)
WORKING LOAD = P/FACTOR OF SAFETY

THICKNESS	ROUGH PLATE				RIBBED PLATE			
	24" SPAN		16" SPAN		24" SPAN		16" SPAN	
	R	DEFL.	R	DEFL.	R	DEFL.	R	DEFL.
1/8"	5900	.31	4300	.11	4800	.28	5200	.15
3/16"	5260	.17	6000	.11				
1/4"	6300	.18	4000	.07	6850	.21	5000	.07
3/8"	4700	.11	5100	.06	5150	.11	5300	.06
1/2"	4200	.07	3200	.03				
3/4"	4800	.05	4200	.02				
1"	3700	.04						
	POLISHED PLATE				WIRED PLATE			
1/8"	7000	.42	7000	.21				
3/16"	6700	.24	7220	.15				
1/4"	4500	.14	5500	.09	4850	15	3670	.04
3/8"					3700	.10	3620	.04
1/2"	5000	.09	4250	.06	4100	.07	3800	.03
3/4"	6200	.08	4400	.03				
1"	4300	.04						

NOTE:– ALL PLATES 8" WIDE — ABOVE ARE MINIMUM VALUES FOR R + DEFL. AS FOUND IN TESTS

annealing and the other as lehr annealing. Kiln annealing is a three or four days' process, and lehr annealing takes five or six hours. There is really no difference as far as the strength of the glass is concerned, lehr annealed glass being as strong as kiln annealed glass. Then, of course, we have this wire glass plate, which is used a great deal for fire protection. It is found by comparison that the wire plate shows in general strength below plain plate.

The President: There seems to be quite a demand for information from the chemists as to the structure of glass. We would be very glad to hear from Mr. Handy as to his opinion of glass.

Mr. J. O. Handy: I would much prefer hearing from some of the chemists who have succeeded in making these fine colored glasses. I do not think my opinions about glass making would be of any great value. As to the composition, I might say first that glass seems to be a mixture of silicates usually of quite definite composition. Anyone interested in that would do well to read Mr. Robert Linton's paper presented before the Society some time ago.* That paper, insofar as I know, is the most thoughtful presentation of the theory of the composition of different glasses which has been written. My own experience with glass has been at the analytical end rather than the synthetic end. Some of our problems are very interesting, but hardly matters of general interest. In one instance, a man started to bottle water and after a while the interior of the bottles became irridescent and flaked off freely; the explanation was that too much alkali had been used in the making of the glass. I do not know that I could add anything more to the excellent papers which have been presented tonight.

The President: The subject is now open for general discussion.

Dr. Brashear: It may interest you to see a specimen of modern optical glass. I have brought with me a piece of what is probably the finest glass yet made for certain optical purposes. This glass has very peculiar properties, one especially,

* Proceedings, Vol. XI., 1895, pp. 119 f.

the property of resisting the action of the atmosphere. It is a boro silicate crown. Prisms made of this glass can lie outside of the window for a year without any moisture accumulating upon them. The surfaces of some of our heavier glasses will not last a day in our moist climate. I have one of the most magnificently corrected objectives of about 3" aperture made from special Jena glass. It had absolutely no color error whatever, that is, in other words, every object appeared through the telescope in its normal color. But it did not last any time. It has a "patina" over it that can be rubbed off, but it is practically opaque to light after a short exposure. In strange contrast with that a piece of glass was sent to me some time ago by the American consul, taken out of an old glass house close to Jerusalem. Its surfaces are bright (though it is not transparent) after perhaps more than a thousand years.

May I add just a word in answer to these gentlemen. I don't believe there is anybody that ought to know as much about the structure of glass and its characteristics as the optician who has to manipulate this material. If we could see into a steel, or any kind of a casting, as we can see into a piece of glass, and learn its characteristics, by the critical methods at our command, our engineers would design things a lot different from what they do now.

About five years ago we had sent us a reflecting telescope mirror 37 in. in diameter and 5 in. thick in which we were asked to cut a hole 3 inches in diameter in the centre. It was a beautiful piece of glass which had already cost probably $4,000. After testing it with a polariscope we concluded not to touch the glass without having the assurance that we would not be held responsible for its breakage, because we were morally certain it would break into a thousand pieces when we undertook to cut it; because of the molecular strain in it. We so telegraphed the owners of the glass and they replied they would take the responsibility. Before undertaking to cut the hole we put a steel band around the disc and drew it together with bolts and pulled on them to an extent of probably twenty tons, of course with a proper lining between the glass and steel band for protection. It was then submerged in water to

keep it at a normal and constant temperature. We had been cutting the hole for about an hour and was about one-fourth of the way through when the disc flew into a thousand pieces and if it had not been for those steel bands probably the men working it would have been seriously injured.

Now the trouble was not in the material of the disc itself but in the annealing. What is annealing? It is nothing more or less than so slowly cooling any such material that its molecules are allowed to arrange themselves into a natural and normal condition without any stress or pull upon one another.

Mr. Macbeth: To say that glass is a silicate does not meet my idea of it at all. It seems to be a fusion of alkalis with silica. The silica is always the principal constituent of it, and it is mixed in all sorts of proportions. The glass maker will usually adapt his proportions in accordance with the temperature of the furnace, from 2650° to 2850° *F.* At 2850° very much better glass can be made than at 2650°. The difficulty with low temperatures being the lower the temperature the more alkali; the more alkali the softer glass, and the more soluble. Lead in respect to solubility is a very important constituent in glass and tends to conductivity of heat, but is not good in chemical glasses. Often it is asked, how long does it take to anneal a piece of glass? Long and short times both. If it is thin ware it will anneal in an ordinary lehr. In case of two heavy parts joined by a light part, in which the ends can be cut off, and the middle part left, the middle is annealed well but the ends are not. If, however, it is to remain a part of the article, in order to properly anneal the heavy part requires bringing it up to a temperature which will probably bend the thin part. We have trouble all the time with things which cannot be well annealed on account of bad designs. We are confronted all the time with these problems. Much of the glass made should be better than it is. It is easier to make it poor.

Soda ash is used extensively in glass. Potash is better for very many of the articles, but the difficulty is it produces what the glass maker calls "stones;" is a good deal more expensive, harder to melt and harder to make into good clear glass.

CORRESPONDENCE.

Questions arising in the Making of Glass.

BY R. L. FRINK,*
Member.

Of the innumerable troubles in the production of first quality of window glass and causes of loss by breakage in the glass business, whether in window, plate, pressed or blown ware, for how many can we give convincing scientific explanation and proof of this cause?

Why is this proof so difficult to produce? Some say it is because glass is an amorphous body and transparent. Is it as made in our factories at all times amorphous, or is all of it ever amorphous? Is breakage and defects caused by mechanical or chemical hetrogenity, and is it due to this imperfect amorphism? I will not here attempt to produce any argument pro nor con, let that come later, neither will I attempt or go into higher mathematics to advance my ideas, as have many others, but will endeavor to confine myself to practice and the results of some investigations started about fifteen years ago with the object of determining why glass was brittle and hard and why sometimes it was more so than others, composition being the same.

In this we will only deal with window glass, for an attempt to go into this subject further would take too much space; besides which all conditions found in other glasses are found in the making of window glass, that is insomuch as these conditions affect those properties which are pertinent to the above questions.

Let us first consider the operation of making glass in an up-to-date factory by the regenerative tank method. The tank is a rectangular furnace with inside dimensions approximating 20x80 ft., having an arched cap over its entire length, whose height is usually about eight feet above the surface of the glass.

* Experimental Engineer, Cleveland, Ohio.

That portion constituting the melting end occupies from 40 to 55 feet of its length. The heat is supplied by gas and air, being brought into the furnace from the regenerators by means of the stack pressure, which is in effect on the opposite side of the furnace from which gas and air enters and which effect is reversed at given intervals, usually every twenty minutes, in order that both sides of the furnace shall be maintained at equal temperatures. This is done usually by butterfly or saucer valves. The quantity of air is regulated by the amount of air valve opening and the stack pressure. The quantity of fuel, if producer gas, is regulated by the quality and quantity made at the producers; or if natural gas is used, by judging from the appearance of the fire as to quantity of gas required, which is done each time a reverse is made; surely not a very accurate or economical method.

The depth of the metal is usually about 48 in., making the weight of metal in the tank about 575 tons; and the surface of which is to be maintained at a temperature of from 2800°*F* at melting end, to 2000°*F* at working end. That portion of the furnace below the necks or air and gas ports being heated solely by radiation from the melting end. This temperature has heretofore not been a matter of degrees nor a question of regulation to any known standard, but merely a regulation to produce certain desirable working properties, the principle of which is viscousity or tenacity in the semi-molten state. However, glass makers are beginning to realize that temperature and combustion are very prominent factors in the making and maintaining a uniform metal.

These materials being charged through the end wall lie like a small iceberg, which they are in temperature comparison, floating on the surface of the molten metal, partly submerged; their upper portion coming in direct contact with the fire as it passes across the furnace, and thereby some portions at times being in a reducing, and the remainder in an oxidizing atmosphere; or at times the gases are all reducing or all oxidizing, depending on the fuel and air supply.

Because of the exposure of this upper portion of the batch to direct or impinging action of the fire, and because of the low heat conductivity of the batch, only the surface for a small depth is affected for some time after charging, and we find that the first effect of the fire is to melt the soda constituents of the batch, which then combine with the silica and we get various sodium silicates. The lime soon becomes heated to the point of decomposition and it combines to form various calcium silicates and during this period of activity comes in contact with its strongest soda neighbor, which because of its strong combining power forces a combination, thereby making what we know as glass. A word that signifies an endless variety of combination of oxides, most "fearfully and wonderfully made."

It is the practical effect produced by these different combinations that I would bring to the especial attention of any speculatively or experimentally inclined individual or individuals, who if they can furnish the correct solution of these problems and *practically* apply their solution will have furnished that which is of greater benefit to manufacturers and mankind, so far as glass is concerned, than the inventions of machines or any other mechanical equipment, for without the proper metal the machines are valueless. Many glass machines for various kinds of product have been pronounced failures for no other reason than that the metal was not fit for the purpose.

We have outlined the method of making glass, a process with which all or nearly all are familiar, and in the first paragraph asked four questions. Let us consider them in their order. First: to how many causes of defects and breakage can we give a satisfactory scientific explanation and practically prove that this explanation is correct? I answer none. Perhaps first in order would have been the question how many causes are there? I answer like our historic Indian friend, "Count the sands of the sea and the stars of the heavens," and *maybe* it will reach the number.

Our second question, "why is this satisfactory explanation so difficult to produce?" May we not well supplement this

question with another, "What is *glass*?" and by answering in scientific detail, find therein the answer of the first? In my opinion, the first can never unconditionally be answered until we can effectually and satisfactorily explain and demonstrate what glass is. Therefore, our answer must be "Because we do not know with what we are dealing."

Our third question, a most difficult one, a complete and scientific answer to which would answer our second, to understandingly answer the third we would have sufficient knowledge for all others. However let us consider a few facts, or call them theoretical deductions if you wish, found by patient study in a practical operating factory making their glass substantially as set forth in the above description, and let us assume that there are two tanks operating, No. 1 using salt cake, No. 2 using soda ash, to supply their soda constituents.

It will be found that the glass from No. 1 with furnace conditions the same, is harder, has a higher softening point, greater strength and is less viscous at 1550°*F* than that in No. 2, analysis showing that their composition is practically the same. Also the metal from No. 1 has the property of producing any impression made in or upon it in the form of a string, cord or wave, to a much greater degree than does No. 2; that it requires a temperature in excess of 1750°*F* to eliminate these defects or to cause the chilled surface of the glass to again amalgamate with the main body, while that in No. 2 will readily amalgamate at 1650°. Or, to be more specific: If a pot of glass from No. 1 be allowed to stand to the open, subject to free radiation and atmospheric influences two minutes and a cold iron is drawn across it within the first 30 seconds, there will be found to exist in any article made from the glass gathered or drawn from this pot, a cord or wave. If this operation be repeated with No. 2 it will be found that it has had but little effect. This can be better demonstrated if the glass is drawn directly from the surface in cylinder form similar to the method of the American window glass machines.

Now, if we take these two samples and cut specimens of 3 in. in diameter from them, including in the specimen a por-

tion of the cord or that part over which we have passed the iron, wash their surfaces with boiled distilled water, alcohol, and ether, dry and weigh; place these samples over platinum dishes in which are 2cc of MF1 containing 30% acid, maintain a temperature of 180°*F* for one hour, remove and heat to 210° over H_2O bath, wash with H_2SO_4 dil. and again heat to 400°*F* gradually until H_2SO_4 is expelled and then boil in HC1 dil. until no sign of a white coat remains on the surface, we will have laid before us, if sufficiently magnified, the molecular mass structure of this metal. You probably will observe to a more or less degree, according to certain tank conditions, that the principal portion is of a brainy appearance, in fact, samples I have photographed compare very well with photos of a brain. However, that of No. 1 will be found to contain in the interstices a distinct crystaline substance as is shown in the accompanying Plate 1, and if observed in transverse section we will see the laminated effect, as denoted by Plate 2, varying somewhat in its crystalography, but all having the same general appearance in transmitted light, in polarized light passing a red plate of the first order they will be found to have somewhat different angles of polarization. Let us call this specimen No. 1 and that from No. 2 tank specimen No. 2.

Now, if we examine specimen No. 2 we will (tank conditions being the same) find this crystaline effect less marked and crystals much smaller or totally absent.

We will now place these samples back on their dishes, which now contain 6cc of HF1, and allow to stand three hours, repeating the remainder of the operation, and we find that the crystals of No. 1 have very materially diminished, while those of No. 2 are about the same, although if none are noticed immediately it is likely some will be seen after careful search. But these are not of the same class as found in No. 2, nor do they show the same properties of polarization.

What is the difference between these crystals which we have seen and those of devitrification, is a question I have been asked many times. I can only answer by asking, is not devitrification only an aggravated condition and are not its crys-

tals only those of greater magnitude than those we have just seen highly magnified. So much for the first part of question three. Howabout the cord or that part where we have placed the cold iron? By careful examination first with a B. & L. 1½-in. objective, 2-in. occular, we find in our 2cc etching of No. 1 that there is a fairly sharp line of demarkation where the cold iron came in contact with the glass. By this I do not mean that there is a print of the rod, but that there is a cord or different structure along well defined lines whose form will be according to the method and manipulation of the metal in making the specimen. It will appear that the specimen has a raised appearance along the cord, as though the acid had not

PLATE 1

PLATE 2.

been as effective there as on the metal surrounding it, and if the specimen was made by drawing vertically from the undisturbed surface of the pot this will be still more pronounced. Not so with our 2cc, No. 2, or at least much less so. In fact, it will be surprising if you find it at all.

How about that part of the etching where 8cc have been used, as above described? On examination we discover that No. 1 has lost this cord almost entirely, while in No. 2 we can see little or nothing of it.

We now have considerable change in the structure along quite well defined lines but entirely different from No. 1; this is

observed through Ob. ⅔ Oc. 2″ as being a densely constructed furrow with two granular edges, or the whole granular with edges of larger granules and in both instances minute crystals are perhaps found between these granules in spots of varying area. Now what has become of the crystals we saw on the main body of the etching? Have they been squeezed out of their magma by the process of cooling, and is this the reason why we do not find them in the cord? But if so, why in No. 2 do we find them more pronounced after getting deeper into the body of the metal even more than where no chill was eftive.

Then while this is no proof, does it not, nevertheless, fairly well answer the latter part of question three in the negative; that all of it is never amorphous?

Now let us make a gathering or a cylinder of glass taken from the same place in the tanks as sample No. 1 and No. 2. Samples from tank No. 1 we will make into a cylinder of single strength thickness, or an average thickness of .093, in and number it No. 3. From tank No. 2 we will make two cylinders, one single, No. 4, and one double strength, the double being .123 in. thick, which we mark No. 5.

Let us cut 34 samples from each. One of each of these we will number 3a, 4a, 5a, which we powder and analyze by these mthods, viz: Fusion in Na_2CO_3, Smith's method (igniting with $CaCo_3$, plus NHC1) and by decomposition with HF1, thereby securing a check on our work. We find that we have an average analysis as follows: Glass from tank No. 1, marked 3a analysis, shows SiO_2 72.07 Na_2O 13.81, CaO 11.70, Fe_2O_3—$A1_2O_3$ 1.79. Glass from tank No. 2, marked 4a analysis shows SiO_2 71.87, Na_2O 14.10, CaO 12.31, $A1_2O_3$—Fe_2O_3 1.53. MgO in both cases being around .42. Sample marked No. 5a from tank No. 2 is practically the same as No. 4r, the results checking very closely.

Nineteen of these samples marked 3, 4 and 5, are now prepared for etching, dried and weighed, then etched as above stated using exactly 8cc of acid and exposed for four hours, care being taken to prevent any loss of material from the sur-

face of the samples or of the solution. After etching is completed the samples are boiled in 10ccHCl and 10ccH_2O, evaporated to dryness and taken up with H_2O and H_2SO_4 and again evaporated to dryness.

The samples are dried at 200°*F*, cooled and weighed. We find that No. 3 average a loss of 11.53 gms, No. 4, 9.77 gms, No. 5 8.166 gms.

We make an analysis of the residue left from washing and boiling the samples in HCl, and of this HCl solution get the following average results: No. 3 Na_2O 14.3%, CaO 11.55, Al_2O_3—Fe_2O_3 1.57. No. 4 Na_2O, 13.99%, CaO 12.12, Al_2O_3—Fe_2O_3 2.398. No. 5 Na_2O 13.72, CaO 11.948, Al_2O_3—Fe_2O_3 2.445. Magnesia being about .42 in all cases. Silica, of course, passes off as silicon fluoride. Their average was found to be for No. 3 72.744%, No. 4 70.652, No. 5 71.424.

The greatest difference found in the values of the respective constituents from the 19 analyses made were as follows: No. 3 Na_2O 2.13, CaO 1.87, Al_2O_3—Fe_2O_3 1.06%, SiO_2 3.86. No. 4 Na_2O 2.54, CaO, 1.6, SiO_2 3.84, Al_2O_3—Fe_2O_3 1.57%. No. 5 Na_2O 1.77, CaO 1.55, SiO_2 3.64, Al_2O_3—Fe_2O_3 1.25.

In the 19 etchings made we find that with salt cake glass No. 3 the soda invariably runs higher than in either of the soda ash glasses (No. 4 and No. 5) and also higher than the analysis of the crushed sample, lime lower and silica higher. In No. 4 the single strength we find that the soda and lime is higher and silica lower than in the double strength, or No. 5. Alumina being lowest in No. 3 and highest in No. 5, although but little difference between 4 and 5. This difference will be found to exist all through directly as the silica differs, varying directly as the silica varies. It will also be seen that the alumina and iron value is nearly 30% higher in the etching than in the total analysis. Further it will be noted from the values given as greatest difference for lime that they are comparatively the same in all three cases, indicating that it is silica and soda that are the variable constituents.

So much for the chemical part, let us look further for physical proof that we do not thoroughly make our glass, or at least that it is not amorphous.

We will take five of these samples and very carefully grind and polish from each side .002 in. and subject it to test for transverse strength and resistance to bending. Comparing these with five that have not been ground and we find that the ground ones cut from No. 3 and No. 4 have lost but 4.4% of thickness, but about 19.5% of their strength; of No. 3, only 12.3%, of No. 4, and taking 4.16% less weight to cause rupture. How is it with No. 5, which loses 3.23% of thickness and 11.2% of its strength?

The remaining sample we cut that we may examine same under the microscope with polarized light and we find that No. 3 is under terrific crushing strain, which is shallow in depth, while No. 4 is comparatively slight but deeper. No. 5 is very heavy, but is not so deep in proportion as is either No. 3 or No. 4.

This would seem to indicate that it at times is crystaline or at least made up of distinct forms or masses, the shape and arrangement of which depends entirely upon conditions. Now let us look at our fourth and last question, viz: "Are breakage and defects caused by mechanical or chemical hetrogenity and is the same due to this imperfect amphorism?"

When I say mechanical hetrogenity I mean a glass composed of a number of silicates in mechanical mixture. Therefore, such being the case, the density of these silicates will, of course, vary according to their composition, and we may readily discover this by means of rays of polarized light. When I speak of chemical hetrogenity I mean a mass in which there exists free and uncombined portions of the constituents or masses, or crystals of certain combined constituents which have separated and which may be seen as in Plate 1.

Now, when we compare two conditions which we have many times found to exist, viz: A condition as indicated by Plate 1, as also that seen in Plate 2, for we at times find the laminated condition shown in Plate 2, without finding the crys-

taline condition as is shown in Plate 1; this is what I call a mechanical mixture. The percentage of breakage which takes place at these times we find as follows: The breakage arising from the mechanical condition can always be discovered some time previous to its development to a point where it would be detected in the production, as, for instance, in conditions as shown in Plate 1, even where this effect is more pronounced than as shown here, we find that the breakage would amount to probably 7% or 8%, while the breakage that would be produced by a condition as shown in Plate 2, has been known to reach 80%. This would therefore indicate that a mechanical condition is far worse than a chemical one. However, inasmuch as a mechanical condition could not exist without a primary inequality of the chemical one, it must again revert us to question three, and the cause of this mechanical condition will be found to exist in nearly every pound of material charged into the furnace, every cubic foot of gas and air that enters, as well as any change in atmospheric conditions, for without all conditions standing in a perfect equilibrium and remaining so, we cannot expect to find uniform chemical conditions, and as a consequence this must produce ununiform physical conditions as are here described. To thoroughly take up a subject of this nature would occupy too much space. However, with a few simple pieces of apparatus and a microscope one may, if so inclined, find in the samples of one week's production of a window glass factory plenty of food for thought and study for some time to come.

There is one more instance which might be cited and one more question which might be asked: "Why is it that a piece of plate glass which has been brought to a perfect "color" by the use of considerable maganese and which, when first made, is perfectly clear, will, after being exposed to the sunlight and weather for six months or a year, be found to have acquired a deep yellow color in transverse sections?" a thing which could not occur, it seems to me, if glass were amorphous.

Our deductions, therefore, may be summed up substantially as follows:

First—That it requires a temperature in excess of a known fixed degree to bring the glass to a condition that it will amalgamate without leaving indications of a physical change, as was shown by the placing on or in it of the cold iron, thereby producing a physical change, as also, no doubt, a chemical one. This could not occur if it were amorphous.

Second—Glass being so extremely sensitive to those conditions which enter into its manufacture, as, composition of the gases overlying it, quality of the fire coming in contact with it, the temperature with which it is melted, the temperature at which it is made into the desired article, the manner in which it is manipulated, and the uniformity with which this temperature is maintained, the chemical composition of its constituents, and as we have seen, the thickness into which it is made; all have their bearing on the successful production of a piece of first quality glass, that can, in my opinion, be considered amorphous.

Third—That changing any one of these elements, bringing it out of a definite relation to the others, causes one or more conditions to exist which will alter the physical or chemical structure, or both, of a mass of glass subjected to these varying conditions.

Fourth—That temperature evidently plays a very important part in maintaining a homogenous compound, is shown by the effect on the single and double strength in tank No. 2, as also the application of the cold iron.

Fifth—That salt cake or soda ash, of which either may furnish a required amount of sodium oxide, do not furnish the same in such a condition as to yield a glass of the same physical properties. A solution of which, in fact, salt cake makers would be very desirous of obtaining, and a solution which I believe we have in part herein.

Engineering Data.

[The Publication Committee solicits contributions of engineering data for publication in the Proceedings. Formulas, Tables and Notes which are of everyday use and which are not found in the standard hand-books, are especially desired. The Committee believes that there is much valuable material in the hands of various members which should be available to all, and that its publication would be very useful. Credit will be given for all contributions. Send data to the Secretary.

Criticisms of, and additions to data already published are requested.

HINTS RELATING TO RIVER PIER CONSTRUCTION.

1. Rock foundation if obtainable.
2. Piles next choice.
3. Gravel or sand if piles cannot be driven more than six or eight feet or will not stand firmly after released from the pile driver leads until sawed off at the required elevation.

First—If rock be found put test hole down to determine the depth of formation before starting masonry.

Second—If pile foundation be decided upon and dredging be required, dredge two or three feet below elevation of cut-off to provide against sedimentation, washing in of refuse that would otherwise come over the tops of the piles between the time of cut-off and final landing of grillage foundation.

Timber grillage is usually composed of 12x12-inch hemlock laid in courses at right angles to each other. Hemlock will crush over piles from one to three inches, depending on the load supported; hence danger of listing. Listing can be prevented by making the bottom or first course of timber of hard wood. As masonry weighs about 150 lbs. per cubic foot listing does not occur to any appreciable extent until after masonry is ten to fifteen feet above water line.

Piers built in navigable water not to exceed twenty feet in depth are cheaper per cubic yard than the same piers would be on land.

Do not design a bridge with a pier located between pool full and the top of the first bank, unless the foundation be rock. If it is to be piles or gravel the excavation will be expensive, the cribbing difficult to hold in place and, generally speaking, for a radius of twenty-five miles from Pittsburgh a wet semi-quicksand is met with. Either put the pier in the river or well out on shore.

It is wise to let a pier season a few days after every twenty feet of rapidly built masonry. If possible let a pier season one week before leveling off the last course for the coping. If no time be allowed for seasoning allow one-half inch per fifty feet of length for settlement of green masonry piers. If, however, the work be done during zero weather and the water, sand and gravel in the concrete be kept

warm and one quart of salt per cubic yard be used the settlement will not be over one-quarter inch per fifty feet.

If it be necessary to protect a pier from floods and ice with a nose or ice-breaker on the up-stream end, it is economical to make the pier symmetrical by placing a duplicate on the down-stream end. Rule of thumb does not demand this. Small coping stone well set and grouted are better than big, expensive stone which are generally poorly set.

Weights of Steel Bridges of Different Types, With Spans up to 550 Ft.

The following formulae for estimating the approximate weights of bridges have been obtained from actual construction and if there is any criticism to find in them it is that they are too close an approximation. The term "Hot Metal Bridge" applies to a structure having a solid buckle plate floor system and sides sufficient to provide protection for river and other travel underneath same during the transit of hot metal from furnaces to the mills.

(1). Ordinary pin connected, through truss, open floor system, single track, $W=7\frac{1}{2} L^2+500L$.

(2). Do. Double track, $W=12 L^2+1000L$.

(3). Double track, through truss, pin connected, solid floor system of furnace sand; hot metal bridge. $W=16 L^2+2800L$.

(4.) Ordinary deck plate girders, single track, open floor, $W=10L^2+350L$.

(5). Do. Hot Metal, $W=12L^2+1500L$.

Where W.=Total weight of steel work, and L.=Extreme Length.

Based on a live load similar to Cooper's class E 50, but with particularly heavy loads on cars suitable for hauling metal around Pittsburgh.

TABLE I.

Ordinary pin connected, through truss, open floor system, single track.

$$W.=7\tfrac{1}{2} L^2+500L.$$

25	17,188	300	825,000
50	43,750	325	954,688
75	79,688	350	1,093,750
100	125,000	375	1,242,188
125	179,688	400	1,400,000
150	243,750	425	1,567,188
175	317,188	450	1,743,750
200	400,000	475	1,920,688
225	492,188	500	2,125,000
250	593,750	525	2,329,688
275	704,688	550	2,543,750

TABLE II.

Ordinary pin connected, through truss, open floor system, double track.

$$W=12\ L^2+1000L.$$

25	32,500	300	1,380,000
50	80,000	325	1,592,500
75	142,500	350	1,820,000
100	220,000	375	2,062,500
125	312,500	400	2,320,000
150	420,000	425	2,502,500
175	542,500	450	2,880,000
200	680,000	475	3,182,500
225	832,500	500	3,500,000
250	1,000,000	525	3,832,500
275	1,182,500	550	4,180,000

TABLE III.

Double track, through truss, pin connected, solid floor system of furnace sand; hot metal bridge.

$$W=16\ L^2+2800L.$$

25	80,000	300	2,280,000
50	180,000	325	2,600,000
75	300,000	350	2,940,000
100	440,000	375	3,300,000
125	600,000	400	3,680,000
150	780,000	425	4,080,000
175	980,000	450	4,500,000
200	1,200,000	475	4,940,000
225	1,440,000	500	5,400,000
250	1,700,000	525	5,880,000
275	1,980,000	550	6,380,000

E. K. MORSE.

Our Topographic Elevations and Atmospheric Pressures.

The elevation above mean tide at Sandy Hook of the zero of the City of Pittsburgh, at foot of Market street, is 697. ft.; pool full of the harbor is 703. ft.; low point on county line down Ohio river is 671. ft.; high points of the county rise to near 700 ft. higher. The river beds rise per mile at rate of 1.5 ft. for the Allegheny and 0.8 ft. for the Monongahela.

The average atmospheric pressure at sea level in our zone is balanced against a vacuum by mercury column of 30 in. at 32°F, or by water column of 34 ft., and in the open is overcome by water vapor tension at 212°F., and it is thus 14.7 lbs. per sq. in. At one mile high the range is from 24.5 in. barometer, 27.8 ft. water suction, and 202°F. water boiling point. The mercury column lowers at first 1 in. for every 900 ft. rise above the sea, and the boiling point of water 2°F. for every 1000 ft. rise. We have here at our many points 200 ft. above the river the barometer about 29 in. The year's range in inches of mercury column for 1907 shown in following table is of the mean height for each month, obtained as the mean of the days' means. And there is given with the dates thereof in the month the highest and the lowest, also the difference of these two.

But there has occurred since, in the first two weeks of 1908, a lowest barometer, almost the lowest ever observed here, in which the barograph line, Sunday, January 12, at 2:50 p. m., dipped to 28.16 for the local station (at 842. elevation), the absolute sea level column corresponding being 29.05. At the sea coast it is reported as having been two-tenths still lower.

As the barometric curve was about uniform in lowering and raising during the 36 hours of sinking and recovery there was not great blow of wind—30 miles an hour from the east, contrary to our prevailing winds, however. Empirically, the wind's pressure is one pound per square foot of surface for a rate of 14 miles per hour, and increases as the square of the rate; thus 66 miles per hour, the highest velocity of the wind observed here, would give a pressure of 22 pounds.

Barometer Observations for 1907 at Pittsburgh by U. S. Weather Bureau. Reduced to Absolute Sea Level.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	30.20	30 12	30.07	29.96	30.00	29.94	29.93	30.03	30.02	30.13	30.00	30.04
Highest	23d	23d	16th	1st	5th	17th	4th	15th	15th	31st	17th	21st
	30.62	30.77	30.53	30.50	30.32	30.29	30.14	30.34	30.39	30.51	30.41	30.52
Lowest	19th	19th	19th	23d	27th	2d	26th	2d	24th	7th	6th	23d
	29.61	29.47	29.60	29.38	29.64	29.62	29.71	29.75	29.57	29.61	29.57	29.26
Difference	1.01	1.30	0.93	1.12	0.68	0.67	0.43	0.59	0.82	0.90	0.84	1.26

January 16, 1908. F. Z. SCHELLENBERG.

Charts, Giving in Graphical Form Information Relative to the Power and Water Consumption of Simple Engines.

Sheet No. 1 gives two curves, from either of which can be obtained a constant, which, used in one of the formulas given on the sheet itself, will give a very close approximation to the indicated horse-power which may be expected of the engine in question. These curves are applicable to nearly all pressures and any assumed back pressure, and therefore either condensing or non-condensing engines. It also shows the theoretical form of indicator card upon which the curves are based, and gives the usual allowances for back pressure for condensing and non-condensing.

Sheet No. 2 contains curves from which the approximate indicated horse-power of simple non-condensing engines operating under 100-lb. steam gauge pressure can be obtained very quickly. It also contains a table giving usual piston speeds and the theoretical and actual steam consumption of engines of various cut-offs. Of course, Sheet No. 2 is not of such general application as Sheet No. 1, but as the majority of the simple engines operate under the conditions for which these curves are made, it will be more generally used than Sheet No. 1.

Sheet No. 3 gives the efficiencies which may be expected of various types of simple engines under various conditions. Of course, with the approximate indicated horse-power obtained from either Sheet No. 1 or No. 2 and the efficiency from Sheet No. 3, the approximate brake horse-power which may be expected from the engine is easily obtained.

Example—What is the indicated and brake horse power of a simple non-condensing engine ten in. dia., 12 in. stroke, running 150 revolutions per minute on 100 lbs. gage pressure, and what mechanical efficiency may be expected; cut off at 25% of stroke?

Solution—Piston speed equals $\frac{2 \text{x} 12 \text{x} 150}{12}$ equals 300 ft. per minute.

P. equals 114.7 lbs. P_3 equals 16.2. E1 equals 0.25.

From sheet No. 1—L equals 0.335.

and K equals 0.585.

From either of the values of L or K above and using the corresponding formula on sheet No. 1, we have

P equals 67.0995 minus 16.3328 equals 50.77 lbs. per sq. in. and 1 H. P. equals $\frac{3.142 \text{x} 10 \text{x} 50.77 \text{x} 1 \text{x} 150}{66000}$ equals 36.25.

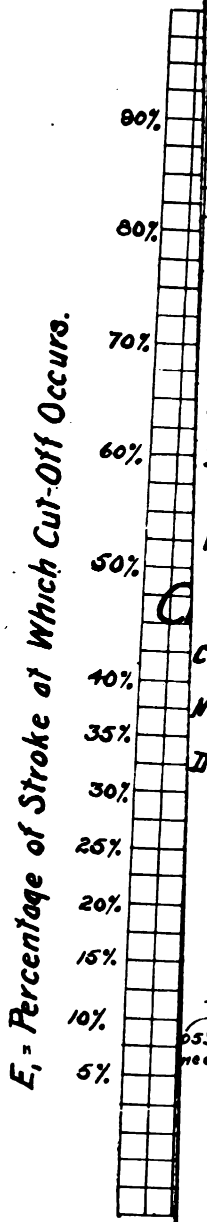
Or since the above engine is in accordance with the basis of sheet No. 2, we obtain from that

K equals 12.08

whence 1 H. P. equals $\frac{12.08 \text{x} 300}{100}$ equals 36.24

From sheet No. 3 we find that the mechanical efficiency of this engine will be about 76% and the brake horse power about 27.36.

J. A. Nelson.



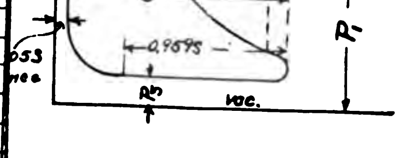
P = Mean Effec. Pres.
P_1 = Abs. Pres at Engine.
P_3 = " Back Pressure.

E_1 = % of Stroke at Cut Off.

S = Stroke in ft.
N = No. Rev. per. min.
L = Factor From Curve
K = " " "
D = Dia. of Cyl. in inchs.

$$IHP = \frac{\pi D^2 P S N}{66000}$$

Condensing P_3 = 2.95 #
Non- " P_3 = 16.2 #
Dry Saturated Steam



PENNSYLVANIA GEOLOGICAL SURVEY.

1899-1906.

LONGITUDES AND LATITUDES.

New Observatory, Riverview Park, Allegheny; Long. 80°—01′—16.94″; Lat. 40°—28′—57.26″.
Old Observatory, Observatory Hill, Allegheny; Long. 80°—00′—44.09″; Lat. 40°—27′—42.17″.

Bench Marks, Pittsburgh and Vicinity.

LOCATION AND DESCRIPTION	HOW MARKED	ELEVATION
Pittsburgh—In foundation of Seventh Ave. Hotel, north side of main entrance.	Aluminum plate stamped 783, Pittsburgh, 1899.	738.383
Pittsburgh—South end of Smithfield Street Bridge, in north face of abutment facing P. & L. E. R. R., 17 ft. east of west side and 9 courses of stone from top.	Seat cut and marked U. S. B. M.	726.730
Brilliant, on P. R. R.—0.3 mile south of, in wall of small culvert south side of R. R.	Bronze tablet stamped 745, Pittsburgh, 1899.	745.354
Wildwood, on P. R. R.—In door sill of west door Penna. Water Co. house.	Copper bolt.	748.829
Benvenue, on P. R. R.—0.25 mile west of station, bridge seat at south end of west abutment for girder bridge over Pittsburgh Junction R. R. tracks.	Bronze tablet stamped 818, Pittsburgh, 1899.	818.184
Homewood, on P. R. R.—In door sill of station (P. R. R. B. M. Ele. 923.43.)	Copper bolt.	923.367
Braddock, on P. R. R.—In door sill to ladies' waiting room (P. R. R. B. M. Ele. 828.88).	Copper bolt.	828.737
Bessemer, on P. R. R.—One mile east of, in face of north abutment at east end, for Union R. R. bridge over P. R. R.	Bronze tablet stamped 760, Pittsburgh, 1899.	759.492

Bench Marks in Pittsburgh and Vicinity.

LOCATION AND DESCRIPTION	HOW MARKED	ELEVATION
Thompson, on P. R. R.—125 ft. south of flag station, at signal tower, 25 ft. west of southbound track, 4 ft. above top of rail, in north wing wall of west abutment for Union R. R. bridge over P. R. R.	Bronze tablet stamped 767, Pittsburgh, 1899.	766.881
Thompson, on P. R. R.—0.33 mile south of flag station, at south end of west abutment of Port Perry R. R. bridge over Monongahela River. P. R. R. bench mark.	Copper bolt.	763.860
Coal Valley, on P. R. R.—County bridge over creek, on coping stone of wall. P. R. R. B. M. Ele. 736.60.	Chiseled square.	736.303
North Bessemer, on B. & L. E. R. R.—One mile south of north end of tunnel, on west side third stone from bottom.	Aluminum tablet stamped 1023, Pittsburgh.	1022.321
Cochran Mills, on B. & O. R. R.—Southwest coping stone of arch bridge.	Aluminum tablet stamped 884, Pittsburgh.	882.546
Bruce—0.5 mile north of, on bridge seat bridge No. 90, B. & O. R. R. B. M.		1002.16
Willock, on B. & O. R. R.—Iron highway bridge at station, on south-east wing wall.	Aluminum tablet stamped 926, Pittsburgh.	925.060
Hayes—Near station, south side of land pier for B. & O. R. R. over-head bridge, R. R. B. M.		760.49
Wildwood, on P. & W. R. R.—One mile north of, northeast bridge seat, small wooden bridge.	Copper bolt.	959.124

Bench Marks in Pittsburgh and Vicinity.

LOCATION AND DESCRIPTION	HOW MARKED	ELEVATION
Wildwood, on P. & W. R. R.—Southwest bridge seat of bridge No. 329, P. & W. R. R. B. M.	Copper bolt.	915.31
Bryant, on P. & W. R. R.—1.5 miles south of station, southeast bridge seat of P. & W. Bridge No. 323, over Pine Creek.	Aluminum tablet stamped 853, Pittsburgh.	853.125
Elfinwild, on P. & W. R. R.—300 ft. west of station, southeast bridge seat (R. R. B. M.)	Copper bolt.	833.29
Glenshaw—300 ft. north of, northeast bridge seat (R. R. B. M.)	Copper bolt.	789.12
Economy, on P., F. W. & C. R. R.—2000 ft. north of, on second step from top of northeast wing wall, bridge No. 15.	Bronze tablet stamped 710, Pittsburgh.	710.119
Ben Avon, on P., F. W. & C. R. R.—Northwest corner P., F. W. & C. R. R. Station, in foundation wall (1.96 ft. higher than R. R. B. M. on Bridge No. 6.	Bronze tablet stamped 728, Pittsburgh.	727.871
Stoops Ferry, on P. & L. E. R. R.—Station (opposite Sewickley) northwest abutment wall of P. & L. E. R. R. bridge over Narrows Run on top of third course from top.	Bronze tablet stamped 721, Pittsburgh.	721.266

Compiled by T. J. Wilkerson.

P. R. R. Bench Marks in Pittsburgh and Vicinity.

DATUM—Mean Tide at Sandy Hook, Levels of U. S. Coast and Geodetic Survey.

LOCATION AND DESCRIPTION	HOW MARKED	ELEVATION
Pittsburgh—City datum.		696.60
Penn Ave.—S. E. corner Penna. Co.'s Office Building.	Shelf.	744.08
Twenty-eighth Street—Pier of bridge.	Shelf.	758.52
Thirty-third Street—West end of south abutment of bridge.	Shelf.	784.26
Pittsburgh Junction R. R. Bridge—N. end of back wall W. abutment.	Copper bolt.	818.34
Shadyside—South abutment of overhead bridge.	Shelf.	851.43
East Liberty—Penn Ave. Bridge S. E. wing wall.	Shelf.	912.44
Homewood—Door sill of station.	Copper bolt.	923.43
Wilkinsburg—Door sill of station.	Copper bolt.	923.25
O.33 Mi. W. of Swissvale—Capstone S. E. side of signal bridge No. 13.	Square.	923.96
Hawkins—Overhead bridge, capstone of S. E. wing wall.	Copper bolt.	886.55
Braddock—Door sill of station.	Copper bolt.	828.88
Brinton—Door sill of station.	Square.	756.80
0.23 Mi. W. of East Pittsburgh—Overhead bridge pier.	Shelf.	752.29
Turtle Creek—625 ft. E. and 33 ft. S. of Ctr. line.	Square.	749.33
Wall—Stone monument E. side of station.	Square.	751.57

Compiled by T. J. Wilkerson.

P. F. W. & C. Ry. Bench Marks in Pittsburgh and Vicinity.

DATUM—Same as P. R. R.

LOCATION AND DESCRIPTION	ELEVATION
Pittsburgh—S. E. corner of Penna. Co.'s Office Building.	744.082
Allegheny—On top steps of Washington Ave. tower, S. E. corner.	757.100
Woods Run—N. E. corner on water table of station.	733.144
Woods Run—N. W .corner of P. F. & I. Co. U. S. B. M.	727.574
W. Bellevue—N. E. corner of Government Building.	728.549
Ben Avon—S. E. corner S. coping bridge No. 6.	725.986
Emsworth—S. E. corner S. coping bridge No. 7.	721.020
Clifton—S. E. corner W. pier to steps.	723.334
Dixmont—N. E. corner E. window sill Gas House.	719.510
Dixmont—N. E. corner N. coping bridge No. 8.	719.628
Glenfield—N. E. corner N. coping bridge No. 9.	719.180
Haysville—S. W. corner E. bridge seat bridge No. 10.	718.579
Glen Osborne—S. E. corner foundation of station.	737.641
Sewickley—S. E. corner E. pier to Umbrella shed.	734.443
Quaker Valley—S. E. corner S. coping Bridge No. 12.	725.353
Shields—S. E. corner bottom step to Mr. Black's residence, E. of Shields.	722.725
Shields—Top of steps N. E. wing wall Bridge No. 13.	709.988
Leetsdale—S. W. corner water table station.	715.530
Fair Oaks—N. E. corner N. coping Bridge No. 14.	711.963
Economy—N. E. corner N. coping Bridge No. 15.	711.516
Logans—S. W. corner E. bridge seat Bridge No. 17.	710.096
Baden—N. E. corner N. coping Bridge No. 18.	710.028
Conway—S. E. corner of S. E. pier to water tub.	707.369
Freedom—E. end of door sill to waiting room.	707.801
Freedom—N. E. corner S. E. pier of signal bridge No. 49.	705.145
Freedom—S. W. corner N. W. pier of signal bridge No. 51.	708.425
Rochester—S. E. corner water table to station.	709.760
W. Rochester—N. W. corner E. bridge seat bridge No. 26.	712.279
W. Rochester—N. W. corner bridge seat bridge No. 27½.	734.097
New Brighton—S. E. corner water table of station.	752.447
Kenwood—N. W. corner E. back wall Bridge No. 29.	749.192
Beaver Falls—N. E. corner door sill to station.	789.190

Furnished by Robert Trimble, Chf. Engr. M. of W., Penna. Co.

P. C. C. & St. L. Ry. Bench Marks in Pittsburgh and Vicinity.

LOCATION AND DESCRIPTION	ELEVATION
Birmingham Station—On N. E. corner of east door sill of station.	766.47
Point Bridge—On wall over north entrance to subway under tracks to station.	771.96
Temperanceville—On east end north coping arch over Main Street.	771.96
Temperanceville—On bottom step S. E. wing wall arch over Saw Mill Run.	729.31
Temperanceville—On west end north coping arch over Wabash R. R.	779.03
Sheraden—Base stone, at south side of east portal tunnel No. 2.	861.13
Ingram—North side of east bridge seat bridge over Steubenville Pike.	873.84
Crafton—On first step of east wing wall north side 10 ft. arch west of Broadhead Cut.	861.63
Lockton—On north side of east abutment bridge over Chartiers Creek.	814.42
Rosslyn—On east end of north coping stone two-arch bridge over road and stream east of Rosslyn Station.	794.80
Carnegie—On north side of east bridge seat bridge over Campbell's Run, east of station.	767.73
Carnegie—One mile west of, on N. W. wing wall of two-arch bridge over Robinson's Run.	791.61

Furnished by W. C. Cushing, Chf. Eng. M. of W.

LIST OF PERIODICALS

On the Tables in the Reading Room of the Society.

American Engineer.
American Machinist.
American Society of Civil Engineers.
American Society of Mechanical Engineers, Proceedings.
Analyst, The
Appleton's Magazine.
Annales de L'Association des Ingenieurs de Gand.
Annaes Scientificos da Academia Polytechnica Porto.
Anales de la Scociedad Centifica Argentina.

Bi-Monthly Bulletin of Amer. Institute of Mining Eng.
Building Management.

Canadian Electrical News.
Cassier's Magazine.
Chamber of Mines, Monthly Journal of the
Chemical News.
Coal.
Coal. Trade Bulletin.
Compressed Air.
Concrete.
Cornell Civil Engineer.

Electric Journal.
Electric Railway Review.
Electrical Review.
Electrical World.
Electrochemical and Metallurgical Industry.
Energy.
Engineer (Chicago).
Engineering.
Engineering Magazine.
Engineering & Mining Journal
Engineering News.
Engineering Record.
Engineering Review.
Engineering World.
Engineers' Club of Philadelphia
Engineering Journal, Canada.

Forum.
Foundry.

Harvard Engineering Journal.

Illuminating Engineer.
Industry.
Industrial Magazine.
Insurance Engineering.
Industrial World.
Iron Trade Review.
Iron Age.

Journal of the American Society of Naval Engineers.
Journal of the Association of Engineering Societies.
Journal of the Franklin Institute.
Journal of the Society of Arts.
Journal of the Society of Chemical Industry.
Journal of the U. S. Artillery.
Journal of the Western Society of Engineers.

Lasker's Chess Magazine.
Les Mois Scientifique et Industriel.
Leslie's Weekly.
Locomotive.
Machinery.
Maschinen Konstrukteur.
Mechanical World.
Mexican Mining Journal, The
Mines & Minerals.
Monthly Journal of the Chamber of Mines.
Municipal Engineering.
McClure's Magazine.
National Engineer.
Official Gazette, U. S. Patent Office (Wash.)
Official Journal, Patents, (London).
Ores and Metals.
Outlook.
Philistine.
Physical Review.
Power.
Practical Engineer.
Papyrus.
Proceedings of the Engineering Association of the South.
Proceedings of the Amer. Institute of Electrical Engineers.
Proceedings of the Academy of Natural Science.
Progressive Age.
Railway & Engineering Review.
Railway Age.
Railway Enginering.
Railway Gazette.
Review of Reviews.
Revista de Construcciones Y Agrimensura.
Revista de Obras Publicas E Minas.
Revue de L' Ingenieur et Index Technique.
Scientific American.
School of Mines Quarterly.
Scientific American Supplement.
Scribner's Magazine.
Sibley Journal of Engineering.
Single Tax Review.
Society of Chemical Industry.
St. Louis Railway Club.
Street Railway Journal.
Technical Index.
Technical Literature.
Technologist.
Technology Quarterly.
Technology Review.
Teknisk Tidskrift.
Transactions of the Liverpool Eng. Society.
Western Electrician.
Western Railway Club

Correspondence.

[This space is open for the use of members desiring information of an Engineering nature.

Industrial Notes.

[The matter below is not paid for, and is not properly classed as advertising, but being necessarily derived from the parties having the appliances on sale, they, rather than the Society, are responsible for the facts presented.]

"Where Water and Fuel Are Scarce or Dear" is the title of an in-interesting circular treating of the heating and purifying of boiler feed water in mining and smelting plants. The pamphlet is published by the Harrisn Safety Boiler Works, 3150 N. Seventeenth Street, North Philadelphia Station, Philadelphia, Pa., and shows that by means of a Cochrane Heater about 6½ lbs. of water may be heated from 60 to 210° F. by 1-lb. of exhaust steam, and further that the 1-¾. of steam will be condensed and added to the boiler feed as pure distilled water, thereby saving 16% of the coal bill, as well as a nearly equal proportion of raw water. Further, heating the water throws out of solution the bi-carbonate of lime and magnesia, which, along with mud, sand and other impurities, are precipitated in the heater instead of being carried over into the boiler. It is pointed out that as the heater does part of the work of the boilers, six boilers and a Cochrane heater can make more steam, while requiring less fuel, less labor and less water, than seven without one.

This pamphlet will be of interest to all who own or operate boiler plants.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII FEBRUARY, 1907 No. 1

ANNUAL MEETING

The 27th Annual Meeting of the Engineers' Society of Western Pennsylvania was held at the Society rooms in the Fulton building, January 3rd, 1907, at 8:15 P. M., Vice President S. M. Kintner presiding, in the absence of the President, 55 members being present.

The minutes of the last Annual Meeting having been printed in due course in the Transactions, and there being no corrections, their reading was dispensed with.

On recommendation of the Board of Directors 32 members were dropped from the rolls for non-payment of dues.

The report of the Board of Direction was read by the Secretary.

REPORT OF THE BOARD OF DIRECTION.

Meetings.

The Board has held nine regular and seven special meetings, during the year, the average attendance at which, including ex officio members, was eight.

The Society has held one annual meeting, ten regular monthly meetings, and three special monthly meetings, at which the average attendance was forty-eight.

As usual no meetings were held nor proceedings published during July and August.

Membership.

Number of members January 1st, 1906	950		
New members added in 1906	84		
		1034	
Dropped from the rolls	59		
Deaths	7		
Resignations	55		
		121	
Number of members January 1st, 1907			913

Income and Expenses.

The income of the Society from all sources for the year was $11,739.21, its expenses $10,664.73, leaving a net surplus of $1,074.48, a decrease over the surplus of 1906 of $570.88, due principally to increase in rent and advance in salaries; this being the first year in which a Secretary was paid for devoting his entire time to the business of the Society.

General.

On April 1st the Society moved to new and more commodious quarters in the Fulton Building on Sixth street, consisting of a reception room, reading room, board room, office, auditorium capable of seating 125 persons, and a coat room; all of which have been handsomely furnished from a fund raised through the efforts of the House Committee. These rooms are now being kept open every week day from 9 a. m. to 6 p. m. and on Saturdays till 10 p. m. for the accommodation of our members.

Towards the close of the year the Charter of the Society was amended by application to the Court and a new set of By-Laws, more in conformity with the needs of the Society, have been passed, which will be in full force at and after the next regular meeting on January 15th. It is believed that with the freer scope thus given our membership will be enlarged and the opportunities of the Society for usefulness increased.

REPORT OF RECEPTION COMMITTEE.

To the President and Directors of the
Engineers Society of Western Pennsylvania.

Gentlemen:

The undersigned take pleasure in presenting their report of operations for the year 1906.

There have been eleven occasions of entertainment throughout the year, beginning with the house warming which occurred on April 21st. The last occasion was upon November 17th, at which we had the largest number, being the visit to the plant of the Dispatch Publishing Company. The Committee had expected to have had another excursion, making an even twelve throughout the year, but it was not found possible to make the purposed arrangements.

The average attendance has been about 160 people and the committee feel especially gratified that the numbers upon some of the trips have been so large, particularly upon those which involved an expense. We also believe that the experiment of having excursions during the summer months, during which there were no other meetings, shows that this will be a success. Furthermore, that occasional excursions arranged for our lady friends will be acceptable to a large number and should be planned in the future. There is given in the following table a statement of the various excursions, with places, dates and number attending:

List of Excursions Made by the Engineers Society During 1906.

1.	April 21st, 1906.	150	House Warming.
2.	April 28th, 1906.	60	Pittsburg Terminal and Warehouse Company.
3.	May 19th, 1906.	125	Filter Plant of South Pittsburg Water Co.
4.	June 16th, 1906.	225	Edgar Thompson Steel Works.
5.	July 21st, 1906.	80	H. K. Porter Company.
6.	Aug. 15th, 1906.	126	Riter-Conley Manufacturing Company.
7.	Sept. 8th, 1906.	150	Isabella Furnaces, Etna, Pa.
8.	Sept. 28th, 1906.	150	H. J. Heinz & Co.
9.	Oct. 20th, 1906.	150	Carnegie Technical Schools.
10.	Oct. 27th, 1906.	270	Bessemer R. R. & Conneaut Harbor.
11.	Nov. 17th, 1906.	300	Dispatch Publishing Co.

The following is a statement of the expenditures and receipts of the Committee showing the net cost to the Society's treasury for the year of $133.53.

Expenses.

Printing Notices	$46 88	
Postage and Telegrams	70 43	
Catering	631 60	
Music	35 00	
Flowers	50 00	
Hire of Boat	30 00	
Hire of Train	215 12	
Sundries	2 50	
		$1,081 53

Receipts.

Banquet	$ 45 00	
Excursion, August 15th	126 00	
Excursion, October 27th	822 00	
		$ 993 00
Net cost		$ 88 53

The principal items of cost on the three most expensive occasions are as follows:

House warming, April 21st	$250 00
Excursion to Conneaut Harbor, October 27th	440. 12
Boat Excursion, August 15th	271 60

Respectfully submitted,

J. N. Camp,
Ralph Crooker,
F. R. Dravo,
E. Gerber,
Edwin H. Haslem,
M. Knowles,
Chairman.

The report of the House Committee was read by its Chairman.

REPORT OF THE HOUSE COMMITTEE.

To the President and Board of Direction,
Engineers' Society of Western Pennsylvania.
Gentlemen:

At the beginning of the present year it had been decided to give up the lease at No. 410 Penn avenue and move the organization to new quarters in the Fulton Building, Sixth Street and Duquesne Way, negotiations for space in said building being under way. Arrangements were afterwards made for a suite on the eighth floor of the Fulton Building,

which includes Rooms 801, 2, 3, 4, 16, 17 and 18. A lease for this suite was signed by our President on February 13th, 1906, covering a period of three (3) years, from April 1st, 1906, to March 31st, 1909. This suite of seven (7) rooms was fitted up into six (6) parts and arranged for Reception Room, Reading Room, Office, Board or Library Room, Coat Room and Auditorium.

On March 31st the personal property of the Society was moved into these new quarters. As the owner of the building had not yet finished the rooms it was some little time before your Committee was able to fit them up for use by the Society's members. This was accomplished, however, in a short time after the rooms were ready for furnishing, and on April 21st they were ready for the "House Warming," which was conducted by the Reception Committee. Following the House Warming, the new quarters were in shape for conducting all the business and functions of the Organization.

House rules for the government of the rooms were formulated and adopted, and a Visitors' Register Book was put into use. New furnishings (a fund for which had been contributed by a number of the members) had been installed, and the Society was therefore placed in a position for a new era of development which it is to be hoped will be finally realized.

When the time came to move the property from the old location, many of the belongings were considered unfit and worthless for future use, therefore many things were disposed of, at that time and since, to the best possible advantage. Following is a list of property sold: Rostrum, a small desk, three tables, three stoves, blackboard, old carpet, lamps, three chairs, a lot of folding chairs, eight (8) bookcases, a small stand, a letter-box, couch and the old fire-proof safe. The sale of these articles amounted to some odd two hundred dollars, which will be shown in detail in the Secretary's and Treasurer's report.

An inventory of the effects that were retained is shown as follows:

Now in reading room: Three leather seated oak rocking chairs, one leather seated oak arm chair, and two framed photographs.

Now in office: One old bookcase, two straight back arm chairs (leather seated), one straight back oak office chair, one oak desk chair, roll top desk, one sectional bookcase, stenographer's desk and writing machine, addressograph, card index file, letter copying press, office table, two framed pictures, two framed photographs, mimeograph, pair of letter scales, and drop light for desk.

Now in board room: Thirteen photographs of past presidents, two leather seated reclining arm chairs (oak).

Now in coat room: Old bookcase, nine framed photographs and one framed map.

Now in auditorium: One projecting lantern, bulletin board, two framed maps, 21 framed photographs, stenographer's desk, rostrum table, three rostrum chairs, four straight back leather seated oak arm chairs and 123 cane seated chairs.

During the year a dictionary and stand were purchased for use in the office; three (3) framed maps were hung in the office; one photograph was received for the collection of past presidents. Two framed engravings were received from the Jones & Laughlin Steel Co. and placed in the auditorium.

The new furnishings before referred to, which comprise the major portion now in use, will be the subject of a special report, and which after formal acceptance by the Society will become its permanent property.

We feel that the year has been a very important one on account of our change in home location, and hope that the future will be productive of a wider scope of influence as time goes on.

We recommend in this connection that our rooms be offered to the use of University and kindred organizations,

so that our organization will be headquarters for all that is influential in the development of scientific and engineering pursuits.

Respectfully submitted,
D. W. McNaugher,
Walther Riddle,
Geo. T. Barnsley,
Chairman.

SPECIAL REPORT ON MATTER OF NEW HOUSE FURNISHINGS.

Pittsburg, Pa., January 3rd, 1907.

To the President, Directors and Contributing Members of the Engineers' Society of Western Pennsylvania.

Gentlemen:

When matters were arranged to install our organization into a new home in the Fulton Building, the question of house furnishings became one of considerable moment to the members of the House Committee. To get the organization properly housed in the new location, where everything would be befitting the place we should occupy in the scientific world, meant that we should spend considerable money in fitting up the rooms. We felt that the Society's treasury could not afford the amount of $2,500.00, which we thought necessary to spend at this time. We therefore took the matter up in a personal way, and asked our prominent members to contribute this sum of money. Coincident with this, we sent out a circular letter to all members of the organization, asking them to contribute even a small sum, so that all would feel an interest in the new work. The result of this appeal to the membership was the receipt of $2,980.50, from 221 members, as per list attached. It may be of interest to you that Andrew Carnegie was the largest contributor, the amount being $250.00; this was followed by President Kennedy with

$200.00; five (5) members gave $100.00 each; seven (7) gave $50.00 each; twenty-five (25) gave $25.00 each, the remainder of the contribution being from $20.00 down to $1.00 each. This sum ($2,980.50), with interest added on daily balance (interest $8.87), made a net total of $2,989.37

From the cash contributions we immediately went to work, and, as soon as the owner of the Fulton Building made the rooms ready, we proceeded to furnish the same, and had them ready for occupancy on April 21st, 1906, the night the house-warming took place. Expenditures for furnishings are as follows:

Mar. 31.—To 3 receipt books @ $1.00 each (cash)..$	3	00
Mar. 29.—Percy F. Smith, printing circular letters, envelopes and postage	56	65
Apr. 17.—Oliver McClintock Co., furnishing and laying carpet	339	30
Apr. 20.—McKenna Bros. Brass Co., 10 cuspidors..	20	00
Apr. 21.—Wm. Stieren Optical Co., barometer and stand and thermometer	17	00
Apr. 24.—Jos. Horne Co., furnishings for reception room, match safes for reading and board rooms	352	15
Apr. 30.—Derby Desk Co., on account	532	00
Apr. 30.—C. Reizenstein Sons, desk lamp, desk set and vase	61	75
May 5.—J. R. Weldin Co., chess set, chess board and engraving and furnishing note paper	38	00
May 5.—F. V. McMullin, lamp shades and muslin.	2	21
May 11.—Wunderly Bros., 20 framed pictures...	271	45
May 17.—Derby Desk Co.	247	60
May 24.—Frank McCombs, lettering doors of Society rooms	14	50
May 29.—Percy F. Smith, printing house rules...	4	75
June 4.—Oliver McClintock Co., making and furnishing muslin screen	4	50

June 7.—J. R. Weldin Co., furnishing visitors' register	16 00
June 9.—Wunderly Bros., framing house rules...	3 75
June 18.—Oliver McClintock Co., furnishing and laying corrugated rubber	35 83
June 23.—Jos. Horne Co., hat and coat racks	72 00
June 23.—Derby Desk Co., on account	200 00
Aug. 9.—Derby Desk Co., on account	166 20
Sept. 10.—Derby Desk Co., clothes pole	8 00
Sept. 28.—Derby Desk Co., table for reading room.	63 00
Oct. 9.—Wunderly Bros., framing map	4 00
(Cash) 200 postage stamps	4 00
Total	$2,537 64

Up to this time there has been a total amount of $2,537.64 expended, leaving a balance on hand of $451.73. With this balance we are arranging for additional things to go into the rooms; viz., a bust of some man eminent in science, a large terrestrial globe for the reading room, an etching for the reception room, etc., which, when installed, will practically use up the balance on hand.

On behalf of the contributors to this fund, the furnishings are now formally tendered to the Society. Upon the formal acceptance by the Society they will become the property of the Society.

In connection with this report, we beg to say that the clock in the reception room was presented by the 1905 Reception Committee from their banquet surplus, to which was added a small amount from the undersigned.

Respectfully submitted,

D. W. McNaugher,
Walther Riddle,
Geo. T. Barnsley,
House Committee.

List of contributors to fund for furnishing new quarters for the Engineers' Society of Western Pennsylvania:

J. A. Atwood	$ 25.00	G. R. Delamater ..	5.00
J. W. Arras	10.00	G. H. Danforth	5.00
Chester B. Albree..	25.00	M. J. Dowling	2.00
Robert M. Allen...	5.00	W. E. Dickson	2.00
Daniel Ashworth ...	2.00	L. C. Daniels	10.00
Harvey Allen	2.00	Geo. A. Davison ...	50.00
Geo. T. Barnsley....	25.00	Alex. Dempster ...	50.00
S. R. Bachtel	5.00	Thos. E. Doyle....	5.00
Jas. H. Baker	5.00	H. L. Dixon	10.00
Chas. W. Bray	50.00	F. R. Dravo	25.00
Geo. F. Boner	1.00	A. C. Dinkey	100.00
Herman F. Busch..	5.00	T. P. Davies	2.00
John T. Bealor.....	10.00	Sumner B. Ely	10.00
M. C. Blest	2.00	Frank I. Ellis	5.00
J. C. & J. F. Barr...	50.00	Isaac W. Frank	25.00
H. L. Bolton	5.00	Chas. F. Franson...	10.00
Wm. G. Boyle	5.00	Henry W. Fisher ..	5.00
J. M. Barnett	5.00	Thos. Fawcus	25.00
Samuel A. Benner..	25.00	W. E. Fohl	10.00
Wm. A. Bole......	25.00	N. H. Finley	5.00
Gustav Berentsen...	5.00	W. B. Fuller	10.00
Geo. W. Barnes	5.00	Wm. L. Fewsmith..	3.00
W. O. Brosius	1.00	Jas. Fawell	100.00
N. Cremer	10.00	R. L. Frink	2.00
J. H. Cook	10.00	Emil Gerber	10.00
Ralph Crooker, Jr...	25.00	S. W. Goodyear ...	5.00
H'y C. Cronemeyer.	3.00	Henry Gulick, Jr....	5.00
J. G. Chalfant	10.00	F. L. Garlinghouse.	25.00
John C. Carr	2.50	Geo. K. Hamfeldt...	10.00
V. R. Covell	5.00	J. M. G. Fullman...	3.00
Thos. A. Collison ..	5.00	Alex. L. Herr......	5.00
W. D. Chester.....	6.00	Geo. W. Hutchinson.	5.00
John J. Convery.....	2.00	Newton F. Hopkins.	5.00
J. N. Chester	5.00	C. N. Haggart.....	2.50
Daniel Carhart	5.00	E. W. Hess	2.00
Andrew Carnegie ..	250.00	W. H. Hegmann...	5.00
J. M. Camp	10.00	J. B. Hogg	10.00
Wm. H. Chadbourn.	1.00	Robert Le C. Hovey.	2.00
Rob't A. Cummings.	25.00	W. C. Hawley	3.00
Chas. Davis	25.00	Herman A. Henpel.	2.00
Samuel Diescher....	10.00	Roy A. Hunt	5.00

J. C. Hemsted.....	5.00
Chas. Hyde	10.00
D. M. Howe	25.00
Edwin M. Herr ...	25.00
S. F. Herr	1.00
O. C. Hoem	5.00
Wm. H. Hays	10.00
R. D. Hall	1.00
S. V. Huber	10.00
F. C. Irvine	1.00
Wilber M. Judd ...	5.00
Frank S. Jackman ..	5.00
Thos. H. Johnson...	10.00
John L. Haines	5.00
F. R. Jennings	2.50
Wm. Larimer Jones.	25.00
Henry D. James ...	5.00
Morris Knowles	15.00
W. B. Klee	25.00
J. L. Klindworth ...	5.00
D. B. Kinch	5.00
F. J. Kimball	5.00
S. M. Kintner	5.00
O. C. Knickerbocker.	2.00
Jas. S. Kaufman ...	5.00
J. W. Kelly	5.00
Julian Kennedy	200.00
Edward Kneeland..	25.00
Richard Khuen, Jr..	10.00
C. F. Klingelhofer...	5.00
John W. Langley..	5.00
P. M. Lincoln	5.00
Robert Linton	10.00
John W. Landis...	2.50
Geo. K. Lehner	5.00
E. D. Leland	5.00
J. P. Leaf	2.00
Jas. K. Lyons	10.00
F. V. McMullin....	5.00
L. A. Meyran	10.00
D. W. McNaugher..	25.00
Camille Mercader ..	10.00
Geo. L. Miller.....	10.00
Lee C. Moore	5.00
Thomas Morrison...	100.00
Thomas McDonald..	5.00
J. D. McBride	3.00
E. S. McClelland....	10.00
Ralph E. Miller	2.50
H. H. McClintic ...	50.00
E. J. Mason	5.00
H. J. McKinley	2.00
Chas. R. McCabe ..	5.00
E. K. Morse	25.00
Edgar M. Moore ...	5.00
F. S. Martin	5.00
Frank E. McKee ...	5.00
George Mesta	100.00
H. P. McClintic....	5.00
C. T. Myers	5.00
Wm. A. Moore	10.00
D. L. McComber ...	5.00
A. G. McKenna	10.00
J. A. McEwen.....	2.00
Louis N. McDonald.	3.00
Jas. R. McGraw ...	5.00
William Metcalf ...	10.00
P. A. Meyer	5.00
W. F. Miller	5.00
Archer E. Myers...	10.00
F. T. McClintock..	10.00
John N. Martin.....	5.00
K. A. Mullenhoff....	2.00
John L. Mullin.....	5.00
J. H. McRoberts...	10.00
J. D. McIlwain.....	5.00
C. D. Marshall	50.00
Geo. H. Neilson...	5.00
J. H. Nicholson....	25.00
R. S. Orr..........	5.00
E. W. Paigny......	20.00
John M. Phillips...	10.00
John W. Paul	2.00
H. S. Page	5.00
A. W. Patton	5.00
John M. Rice	2.00
R. B. Rose	5.00
Thos. P. Roberts...	5.00

Jas. Ramsey, Jr.....	25.00	Benj. Thompson....	5.00
M. L. Rogaliner.....	1.00	S. L. Tone	20.00
Walther Riddle	10.00	Samuel A. Taylor...	10.00
Geo. T. Snyder....	5.00	Maynard A. Tenney.	3.00
W. H. Singer	20.00	Chas. H. Umsted ..	2.00
Jos. A. Shinn	3.00	Philip Vierheller...	2.00
Fred C. Schatz	5.00	Lee Whittaker	3.00
E. R. St. John	3.00	W. H. Wheeler	5.00
Ira A. Shoff	5.00	Henry L. Waters..	4.00
R. D. Smith	10.00	C. N. Wheeler......	10.00
Chas. G. Smith	10.00	Frank B. Ward ...	5.00
W. L. Shaw	5.00	Louis B. Whitney..	5.00
B. W. Stone	5.00	Homer E. Whitmore	2.00
G. A. Suckfield	2.50	T. Sidney White...	5.00
W. L. Scaife	10.00	Frank Wilcox	10.00
J. S. Sloan	1.00	N. C. Wilson	5.00
Wm. L. Sibert	3.00	T. F. Webster	25.00
H. C. Seipp	5.00	Ralph C. Wood	5.00
H. W. Stevenson ...	2.00	T. B. Wylie	5.00
Chas. F. Scott	20.00	J. E. Whittlesey....	2.00
Emil Swensson	100.00	Frank L. White	1.00
Robert Swan	50.00	W. G. Wilkins	50.00
Chas. S. Steinmeyer.	2.00	John P. Young	3.00
Henry C. Shaw....	10.00	P. A. Young	2.50
McGilroy Shiras ...	10.00		
Edw. B. Taylor.....	25.00	Total of	
E. J. Taylor	10.00	Contributions,	$2,980.50

The Secretary read the report of the Publication Committee as follows:

REPORT OF THE PUBLICATION COMMITTEE.

Gentlemen:

Apart from the routine business that has been transacted almost entirely by our Secretary, there has been but one event of sufficient importance to mention at this time. For some years past the advertising has been in the hands of a contracting agent, Mr. Ensign, and a canvasser, at the expense of this Society. The latter was quickly dispensed with, but it took some negotiating to cancel the Ensign contract, which, however, was finally accomplished on March 29th, 1906, by our President, Mr. Julian Kennedy, and myself. Almost immediately our receipts from advertising more than doubled and have been our principal source of revenue. It is my belief that the revenue from this source alone has saved the Society from a deficit this fiscal year.

I wish to take this opportunity of urging upon the next Chairman of the Publication Committee, and all members of this Society, the desirability of enlarging our field of advertising as far as we can consistently with the dignity of this Society.

Respectfully submitted,

E. K. Morse,
Chairman.

REPORT OF THE FINANCE COMMITTEE.

Mr. Lyons, Chairman, said:

On behalf of the Finance Committee I have to report that we have audited the accounts of the Secretary and Treasurer and found them correct; have examined the bonds in the safe deposit vault and found them intact; and have satisfied ourselves that the bank balances agree with the figures as given by the Treasurer.

ANNUAL REPORT OF THE TREASURER.

The President and Board of Directors, Engineers' Society of Western Pennsylvania, Pittsburgh, Pa.

Gentlemen:

The Treasurer takes pleasure in presenting the following exhibit of the finances of the Society for the year ending January 1st, 1907, as shown by his books at that date:

Cash receipts from all sources	$11,739 21
Operating expenses	10,664 73
Excess of receipts over expenses	$ 1,074 48

Collections in Detail.

Dues: 1903, Non-Resident	$ 5 00	
Dues: 1904, Non-Resident	10 00	
Dues: 1904, Non-Resident	8 00	
Dues: 1905, Non-Resident	50 00	
Dues: 1905, Resident	256 00	
Account 1906	12 00	
Account 1906, Non-Resident	970 00	
Account 1906, Resident	4,408 00	
Account 1906	294 04	
Account 1907, Non-Resident	30 00	
Account 1907, Resident	32 00	
Account 1907	14 00	
		$ 6,089 04
Initiation fees	420 00	
Life membership	100 00	
		520 00
Rent	209 50	
Household goods	206 35	
		415 85
Sale of Proceedings	623 37	
Advertising	2,606 46	
		3,229 83

Interest general fund	54 39	
Interest permanent fund	330 58	
Interest building fund	59 70	
		26 27
Buttons		2 00
Old periodicals	9 42	
Junk	16 85	
		444 67
Entertainment		993 00
Rebate on insurance		8 55
Special contribution		10 00
		$11,739 21

Expenses in Detail.

ADMINISTRATION.

Secretary's salary	$1,800 00	
Clerk's salary	630 00	
Attendant at rooms	8 75	
Telephone	98 85	
Printing and Stationery	125 35	
Postage	179 91	
Express and messenger	3 40	
Commission to collector	63 00	
Rent safe deposit box	5 00	
Office supplies	69 08	
		$ 2,983 34

ENTERTAINMENT.

Printing notices	$ 46 88	
Postage	70 43	
Catering	631 60	
Music	35 00	
Flowers	50 00	
Hire of boat	30 00	
Hire of train	215 12	
Sundries	2 50	
		$ 1,081 53

HOUSE.

Rent	$2,056 64	
Ice water	39 00	
Towel service	20 00	
Light and heat	83 58	
Moving	70 34	
Repairing lantern	16 60	
		$ 2,286 16

LIBRARY.

Standard dictionary	$ 23 75	
Binding	6 90	
Express	2 25	
Miscellaneous	70	
		$ 33 60

SOCIETY MEETINGS.

Printing	$ 154 87	
Postage	121 50	
Reporting Meetings	130 00	
Lantern Slides	4 20	
Express	50	
		$ 411 07

CHEMICAL SECTION.

Reporting meeting		$ 10 00

MECHANICAL SECTION.

Advance copies	$ 35 20	
Postage	34 05	
Reporting meetings	80 00	
Miscellaneous	1 00	
		$ 150 25

STRUCTURAL SECTION.

Postage	$ 22 35	
Reporting meetings	80 00	
		$ 102 35

PROCEEDINGS.

Printing eleven issues Proceedings	$1,266 95	
Printing reprints	243 25	
Illustrations	127 40	

Binding	21 00	
Express	12 45	
Envelopes	25 40	
Postage	170 37	
Copyright	5 00	
Old Proceedings	11 50	
Miscellaneous	2 10	
Refund	3 50	
		1,888 92

ADVERTISING.

Printing	$ 797 25	
Envelopes	2 00	
Postage	26 91	
Solicitor's Salary	45 00	
Solicitor's commission	17 28	
Legal expense	100 00	
Rights of F. A. Ensign	100 00	
Miscellaneous	9 55	
		$ 1,097 99

MEMBERSHIP LIST.

Printing	$ 212 75	
Illustrations	1 40	
Postage	57 00	
Envelopes	1 60	
		$ 272 75

INDEX.

Five hundred copies	$ 300 00	
Covers	10 00	
Envelopes	1 60	
Postage	30 17	
		$ 341 77
Dues American Society for Testing Materials		$ 5 00
Total		$10,664 73

The funds of the Society, not invested, are kept under three separate accounts, all with the Guarantee Title & Trust

Co. The following is a condensed exhibit of the condition of each of these accounts:

Checking Account:

Balance, January 1st, 1906	$ 756 96	
Transfer of Key Fund	25 00	
Interest, Permanent Fund	330 58	
Interest, Checking Account	54 39	
Dues and other Collections	10,693 96	
		$11,860 89
Disbursements: Operating Expenses...	$10,664 73	
Transferred to Other Accounts........	114 42	
		$10,779 15
Balance		$ 1,081 74

Permanent Fund:

Balance, January 1st, 1906.............	$ 202 61	
Life Memberships	200 00	
Initiation Fees	490 00	
		$ 892 61

Building Fund:

Balance January 1st, 1906	$ 338 17	
Interest	59 70	
		$ 397 87
Total Balances		$ 2,372 22

Investments.

BUILDING FUND.

	COST.
One, $1,000.00, Butler Walter Company, 5 per cent. bond, No. 9, matures September 2, 1931......	$ 1,025 00

PERMANENT FUND.

One, $1,000.00, Butler Water Company, 5 per cent. per cent. bonds No. 317-318, mature October 1, 1839	2,020 00
Two $1,000.00, Portsmouth, Berkeley & Suffolk Water Company, 5 per cent. bonds, No. 465-466, mature November 1, 1944	2,000 00

One, $1,000.00, Manufacturers Light & Heat, 6 per cent. bond, No. 442, Series K, matures May 1, 1914	1,010 00
One, $1,000.00, Manufacturers Light & Heat 6 per cent. bond, No. 1183, matures September 2, 1909	1,010 00
Total	$ 7,065 00

Respectfully submitted,

A. E. Frost,

Treasurer.

SECRETARY'S REPORT FOR THE YEAR 1906.

The President and Board of Directors, Engineers Society of Western Pennsylvania:

Gentlemen:

Membership January 1, 1906			950
At the Annual Meeting, January 5, 1906, there were dropped	59		
Deaths during 1906	7		
Resignations	55		
Total loss		121	
Elected to Membership, 1906	87		
Matriculated		84	
Net loss			37
Membership January 1st, 1907			913

MEMBERS IN GOOD STANDING.

Honorary Members	7
Life Members	3
Paid 1907	10
Paid, 1906	794
Total	814

MEMBERS IN ARREARS.

		Amount Owing.
Owe 1906	60	$ 420 00
Owe 1905-6	29	426 00
Owe 1904-5-6	6	144 00
Owe 1903-4-5-6	4	116 00
	99	$ 1,106 00

COMPARISON INCOME 1905-6.

	1905 Amount.	Per Cent.	1906 Amount.	Per Cent.
Dues	$ 6,879 17	66.0	$ 6,089 04	51.2
Life Membership Initiation Fees	535 00	5.2	520 00	4.6
Rent	893 00	8.6	209 50	1.9
Household Goods	....	....	206 35	1.9
Buttons	4 00	....	2 00	....
Sale of Proceedings	248 05	2.6	623 37	5.4
Advertising	1,440 70	14.0	2,606 46	22.4
Interest, General Fund	107 51	....	54 39	....
Interest, Build'g Fund.	43 63	3.6	59 70	4.0
Interest, Perm't Fund.	201 60	....	330 58	....
Entertainment	....	....	993 00	8.6
Rebate on Insurance	....	....	8 55	....
Special Contribution	....	....	10 00	....
Junk	54 33	....	16 85	....
Old Periodicals	....	....	9 42	....
Totals	$10,406 99	100.0	$11,739 21	100.0

COMPARISON EXPENSES 1905-6.

	1905 Amount.	Per Cent.	1906 Amount.	Per Cent.
Administration ....$	2,390 73	27.2	$ 2,983 34	28.1
Entertainment	104 60	1.2	1,081 53	10.2
House	1,920 12	22.0	2,286 16	21.6
Library	217 76	2.5	33 60	.3
Society Meetings	499 98	5.7	411 07	3.8
Chemical Section	10 00	.1	10 00	.1
Mechanical Section....	172 98	2.0	150 25	1.4
Structural Section....	130 50	1.5	102 35	.8
Proceedings	2,681 55	30.6	1,888 92	17.7
Advertising	429 16	4.9	1,097 99	10.3
Membership List	194 25	2.2	272 75	2.5
Index	....	....	341 77	3.2
Miscellaneous	10 00	.1	5 00	0.0
	$ 8,761 63	100.0	$10,664 73	100.0
Total Postage ....$	701 93	8.0	$ 712 70	6.7
Total Printing and Stationery	2,787 16	31.8	2,923 10	27.4

ELECTION OF OFFICERS.

The next order of business was the election of officers and as the Chairman was a candidate, he asked Mr. Lyons to take the chair.

Committee on Nominations presented the following candidates for 1907:

President, S. M. Kintner,

Vice-President, Geo. T. Barnsley,

Treasurer, A. E. Frost,

Secretary, Edmund Yardley,

Directors (Two Years)

R. A. Cummings, Walther Riddle.

Directors (Three Years)

F. Z. Schellenberg, J. O. Handy.

There being but one nominee for each office the Secretary was directed to cast the ballot of the Society for the election of the nominees named by the committee.

The President appointed Mr. Fisher and Mr. Bole to escort the newly elected President to the chair.

There being no further business before the meeting and the retiring President not being present to deliver an address* the meeting adjourned at 9:30 P. M.

F. V. McMULLIN,
Secretary.

*This address was delivered at the regular meeting, January 15th.

ANNUAL BANQUET.

The Annual Banquet of the Society was held at the Hotel Schenley on the evening of January 12th; about 250 guests being present.

Mr. Isaac W. Frank, President United Engineering & Foundry Co., acted as Toastmaster.

Speeches were made by:

The Mayor, George W. Guthrie,

"Municipal Activities."

Mr. John D. Shafer, Judge, Court of Common Pleas,

"Law and Engineering."

Mr. Walter M. McFarland, Vice President, American Society of Mechanical Engineers,

"National Engineering Societies."

Col. Henry P. Bope, Vice President of the Carnegie Steel Co.,

"Commercialism."

Mr. James F. Hudson, Editor, Pittsburgh Dispatch,

"Recollections."

MONTHLY MEETING OF THE SOCIETY.

The 271st regular monthly meeting of the Engineers' Society of Western Pennsylvania was held at the Society's rooms, Fulton Building, Pittsburgh, Pa., Tuesday, January 15, 1907, at 8:00 P. M.

The meeting was called to order by President Kintner, with 44 members and visitors being present.

The minutes of the last meeting were read and approved.

The President anounced the Standing Committees for the year, as follows:

Finance: J. K. Lyons, Chairman, F. V. McMullin, Louis P. Blum.

Publication: R. A. Cummings, Chairman; J. L. Klindworth, H. W. Craver, C. L. Livingston, R. D. De Wolf, T. J. Wilkerson, Willis Whited.

Entertainment: Walther Riddle, Chairman; S. B. Ely, P. M. Lincoln, E. H. Haslam.

House: J. O. Handy, H. D. James, F. C. Schatz.

The President: Our peculiar position at the present time, being in between two sets of By-Laws, makes it advisable to present a list of applicants for membership and have it acted on to-night. After this ,however, the new By-Laws provide for their election by the Board of Direction.

The report of the Board of Direction was read recommending seven applicants for membership.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

The paper for the evening, on "Some Modifications in Blast Furnace Construction," was read by the retiring President, Mr. Julian Kennedy.

After a general discussion which was participated in by Messrs. Albree, Anderson, Brashear, Babbitt, Flanagan, Handy, James, Morse, Muellenhoff, Schellenberg, Starrett and Stucki, the meeting adjourned.

EDMUND YARDLEY,
Secretary.

ANNUAL MEETING OF THE CHEMICAL SECTION.

The fifteenth annual meeting was held at the Society rooms January 17th, 1907.

The Chairman and Vice Chairman being absent the meeting organized at 8:30 P. M. by calling Prof. F. C. Phillips to the chair; the Secretary of the Society acting as Secretary of the meeting, in the absence of Mr. Craver. Twenty-two members and visitors were present.

The minutes of the fourteenth annual meeting were read and approved.

No reports were presented.

The list of nominations presented at the December meeting was read. No other nominations being made the Secretary was instructed to cast the ballot electing the following officers:

Chairman, Charles Henderson Rich,
Vice Chairman, Charles Bernard Murray,
Secretary, Harrison Warwick Craver,
Directors { Henry C. Babbitt,
Geo. O. Loeffler.

On invitation of Dr. Phillips Mr. Rich then took the chair and conducted the meeting.

The one hundred and forty-sixth regular meeting was held, immediately after the adjournment of the Annual Meeting, in connection with the Pitsburgh Section of the American Chemical Society.

The minutes of the regular meeting were read and approved.

Prof. Phillips reported progress from the Alloy committee.

As the next meeting of the Allied societies is likely to be at the Technological Institute it was resolved that the place of meeting should be left in the hands of the Chairman.

A paper on the "Atomic Weight of Tungsten" was read by Dr. T. W. Taylor, and was discussed by H. E. Walters, F. C. Phillips, and D. L. Johnson, after which the meeting adjourned at 9:30 P. M.

ANNUAL MEETING OF THE STRUCTURAL SECTION.

The annual meeting of the Structural Section was held Tuesday, January 22nd, in the Reception Room, at 8:00 P. M, W. M. Judd, Vice-Chairman, in the chair. Fifteen members were present.

The minutes of the last Annual meeting were read and approved.

Chairman Cummings being unable to attend, sent his annual address to the Secretary, and it was next read by the Secretary

Election of Officers:—The report of the Nominating Committee was read as follows:

Chairman, Richard Khuen, Jr.,
Vice-Chairman, E. W. Pittman,
Secretary, A. E. Duckham,
Directors { L. J. Affelder, Wm. M. Judd.

The point of order having been raised by Mr. Wilkerson that as the new By-Laws do not provide for a separate Secretary for the Section, but do provide for three Directors instead of two, that the candidate nominated by the Commitee for Secretary be nominated for the third Director.

Mr. Wilkerson's suggestion being put in the form of a motion was duly seconded and carried.

On motion of Mr. Livingston the Secretary was instructed to cast the ballot of the Society for the election of the persons nominated by the Committee, as their nominations were amended by Mr. Wilkerson's motion; making the officers elected as above except A. E. Duckham, who is an additional Director instead of Secretary.

The Annual meeting adjourned.

The regular Monthly meeting then convened.

Secretary Yardley, taking up the duties of Secretary of the Section, as required by the By-Laws, then read the minutes of the last meeting. There being no corrections, they were approved.

The result of the postal card ballot sent out in respect to disbanding the Section having resulted as follows:

In favor of continuing the Section.......43

In favor of disbanding the Section.......26

Mr. Affelder moved "That it is the sense of this meeting that the officers confer with the officers of the Mechanical Section with a view of combining the two Sections."

Mr. Moore, chairman of the Mechanical Section, moved that the chair appoint a committee to meet with a similar committee from the Mechancal Section to talk this matter over informally and report the result of the conference to the Mechanical Section at its next meeting. After which the whole matter can be referred to the Board of Direction at its meeting February 9th, for final action.

The chair appointed next Saturday at 12:30 P. M. at the rooms of the Society, as the time and place of such meeting.

The paper of the evening on "Construction of Reinforced Concrete Pipe Sewers was read by J. F. McMichael: Nonmember, and discussed by Messrs. Judd, Morse, Jno. F. Johnson, Affelder, the Secretary and the Chairman. After which on motion of Mr. Morse a vote of thanks was extended to the speaker of the evening for his kindness in giving us this paper.

Meeting adjourned at 10 P. M.

QUESTIONS AND ANSWERS.

UNDER THIS HEADING SPACE WILL BE RESERVED FOR QUESTIONS AND ANSWERS ON SUBJECTS PERTAINING TO THE MATTERS OF THIS PUBLICATION.

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OFFICERS FOR 1907.

President.
S. M. KINTNER.
Vice-Presidents.
J. K. LYONS, GEO. T. BARNSLEY.
Treasurer, A. E. FROST. Secretary, EDMUND YARDLEY.
Directors.
E. K. MORSE, ROBT. CUMMINGS,
A. R. RAYMER, J. O. HANDY,
WALTHER RIDDLE, F. Z. SCHELLENBERG.

STANDING COMMITTEES:

Finance Committee,
J. K. LYONS, Chairman,
LOUIS. P. BLUM. F. V. McMULLIN,

House Committee.
J. O. HANDY, Chairman.
H. D. JAMES, F. C. SCHATZ.

Publication Committee.
R. A. CUMMINGS, Chairman,
J. L. KLINDWORTH, R D. DeWOLF,
H. W. CRAVER, T. J. WILKERSON,
C. L. LIVINGSTON, WILLIS WHITED.

Entertainment Committee:
WALTHER RIDDLE, Chairman,
S. B. ELY, P. M. LINCOLN,
E. H. HASLAM.

CHEMICAL SECTION.
CHAS. H. RICH, Chairman.
C. B. MURRAY, Vice-Chairman.
Directors.
H. C. BABBITT, G. O. LOEFFLER.

MECHANICAL SECTION.
Chairman, SUMNER B. ELY.
Vice-Chairman, WM. C. HAWLEY.
Directors.
E. H. HASLAM, W. H. WHEELER.

STRUCTURAL SECTION.
RICHARD KHUEN, Jr., Chairman,
E. W. PITTMAN, Vice-Chairman.
Directors.
L. J. AFFELDER. W. M. JUDD.

PROCEEDINGS OF THE
ENGINEERS SOCIETY
OF WESTERN PENNSYLVANIA

Published Monthly, 10 Months of the Year. Edited by the Secretary under the direction of the Publication Committee.

No paper read before the Society shall be published in any magazine or journal before its appearance in the Proceedings, and no paper previously published shall be published in the Proceedings without the sanction of the Board.

The Board reserves the right of supervision of papers and illustrations.

The Society will mail monthly, except August and September, to its members, correspondents and advertisers, postage prepaid, a copy of the Proceedings; each one containing the minutes of and the papers read at the regular meeting and meetings of the Chemical, Mechanical and Structural Sections.

An author of a paper is entitled to 25 copies of the Proceedings containing his paper.

The Proceedings are for sale at the following prices:

1 to 10 copies,	50c	apiece.
10 " 50 "	35c	"
50 " 500 "	25c	"
500 and over	20c	"

Subscription price $5.00 per annum. To colleges and public libraries who agree to bind and catalogue, subscription price is $1.00 per annum.

Back volumes are for sale at the following price: Volumes 1, 5, 6, 7, 8, 9, 10, paper bound, $2.00; cloth bound, $2.75.

Sets of Volumes 11, 12, 13, 14, 15, 16 ready for binding, $2.00; bound in cloth, $2.75.

Index to first twenty volumes of Proceedings, $1.00.

Volumes 17, 18, 19, 20, ready for binding, $5.00; cloth bound, $5.75.

Volumes 2, 3, 4, cannot be furnished.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII MARCH, 1907 No. 2

MEETINGS OF THE BOARD OF DIRECTION.

A special meeting of the Board for the purpose of taking action on delinquents, and receiving reports of the Committees for the year 1906, was held January 2nd, 1907, at 8:00 P. M.

On motion it was directed that the clerk, Miss Olive B. Kalar, be paid for the time deducted from her pay on account of absence during her sister's illness.

The reports of the Reception Committee, Publication Committee, Treasurer and Secretary were read and accepted.*

A committee consisting of Knowles, Morse and McMullin was appointed to write up the History of the Ensign Contract for future reference.

Appropriation of money for payments of the Banquet was authorized.

Adjourned.

The regular Monthly Meeting of the Board was held Saturday, January 5th, at 8:00 P. M., six members being present.

President Kintner announced the Standing Committees for the new year. (See Minutes, page 26.)

The rent of Auditorium to the Foundrymen's Association was fixed at $8.00 per night for the year 1907.

* These reports will be found on pages 1-22 of Minutes.

The Secretary was authorized to keep the rooms of the Society open Saturday evenings for the next three months, and to pay the attendant $1.00 per night.

Adjourned.

The regular Monthly Meeting of the Board was held Saturday, February 9th, at 8:00 P. M., seven members being present.

The salary of the Secretary for the Fiscal year was fixed at $150 per month.

Additional Help.—The Secretary was authorized to hire some additional help to look after advertising, at an expense not exceeding $30.00, and was allowed $6.00 already expended by him.

Cataloguing the Library—

The bid of Mr. McClelland for cataloguing the Library, amounting to $125.00, was accepted.

Committee on Timber Tests—

A letter received from Mr. E. K. Morse, Chairman, advised that a continuation of this committee was undesirable and useless.

Adjourned. EDMUND YARDLEY,
Secretary.

MONTHLY MEETING OF THE CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section of the Engineers' Society was held with the Pittsburgh Chapter of the American Chemical Society, at the Carnegie Technical Schools, Pittsburgh, Thursday, February 21st, 1907.

James E. Aupperle exhibited and demonstrated his apparatus for determining Carbon in Iron by direct combustion in oxygen.

MONTHLY MEETING OF THE SOCIETY.

The 272nd regular monthly meeting of the Society was held Tuesday, February 19th, 1907, at 8:00 P. M.

President Kintner presiding; 160 members and visitors being present.

There being no business before the meeting, except to read off the list of members who have joined the Society in January, the following list was read by the Secretary:

ANDERSON, HAROLD STANLEY, Secretary to General Manager, Jones & Laughlin Steel Co., Pittsburgh.	J. L. Klindworth, F. S. Slocum, M. J. Dowling.
GREER, JOHN WILLIAM, Mgr. Pittsburgh District, Cleveland Pneumatic Tool Co., 1224 Bessemer Building, Pittsburgh, Pa.	John H. Thompson, E. Gerber, J. K. Lyons.
McQUILLEN, JOHN J., Manager of Sales, 1114 Frick Building, Pittsburgh, Pa.	C. G. Dunnells, M. J. Dowling, Ralph Crooker, Jr.
SHINN, EDMUND WOODRUFF, Mechanical Engineer, 5620 Wilkins Avenue, Pittsburgh, Pa.	F. Z. Schellenberg, J. A. Shinn, S. R. Bashtel.
STEESE, MARCUS CASSIDY, Superintendent Blast Furnaces, La Belle Iron Works, Steubenville, Ohio.	W. Forstrom, Walter Kennedy, Thos. McDonald.
WITT, CHAKLES VICTOR, General Manager, James McNeill & Brother Co., Pittsburgh, Pa.	K. F. Stahl, Herman Laub, Victor Beutner.

The paper for the evening on Pitsburgh Subways was read by its author, E. K. Morse. Additional papers on different phases of the subject were communicated by Messrs. Renshaw, Willis Whited, Thos. H. Johnson, Robt. A. Cummings, L. H. Thullen and William Clifford and the subject was further discussed by Messrs. Bole, Schatz, Winter and Ely.

Meeting adjourned at 10:00 P. M.

EDMUND YARDLEY,
Secretary.

ANNUAL MEETING OF THE MECHANICAL SECTION

The Annual Meeting of the Mechanical Section was called to order at 8:00 P. M., February 5th, by the Chairman, Lee C. Moore, 18 members and guests being present.

The report of the Board of Directors was read by the Vice-Chairman, Chester B. Albree.

An address by Mr. Lee C. Moore, the retiring Chairman, was read.

The Nominating Committee recommended the following nominees for officers for the ensuing year:

Chairman—Sumner B. Ely.
Vice-Chairman—Milton W. Hogle.
Directors—E. H. Haslam, Walter H. Wheeler.

There being but one ticket nominated, the Secretary was directed to cast the ballot for the nominees.

Annual Meeting then adjourned.

REGULAR MEETING OF THE MECHANICAL SECTION.

The regular meeting was then called to order by the new Chairman, Mr. Sumner B. Ely.

The report of the joint committee of the Structural and Mechanical Sections, recommending the Sections meet on the first Tuesday of each alternate month, was discussed and adopted.

The next meeting of the Mechanical Section will therefore take place on April 2nd.

There being no further business before the Sections, the members listened to an address by Chester B. Albree on **An Account of Some New Work,** which was discussed by Messrs. Stucki, Flanagan, Whitman and Ely.

The Section adjourned at 10:00 P. M.

EDMUND YARDLEY,
Secretary.

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ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII APRIL, 1907 No. 3

MONTHLY MEETING OF THE BOARD OF DIRECTION.

At the regular meeting night, March 9th, 1907, only four members were present. This not being a quorum, no business could be finally settled, but it was transacted *provisionally* and submitted to absent members for approval. In this way the following members were elected:

	ENDORSED BY
BIRNEY, E. H., Asst. Supt. Rolling Mills, Jones & Laughlin Steel Co., Pittsburgh, Pa.	Frank S. Slocum, R. B. Kernohan, M. J. Dowling.
HUFNAGEL, F. B., Supt. Rolling Mills, Jones & Laughlin Steel Co., 912 Bellefonte St., Pittsburgh, Pa.	R. B. Kernohan, M. J. Dowling, F. S. Slocum.
FRANCIES, WILLIAM HUGH, Civil Engineer, 709 Liberty St., Allegheny, Pa.	Geo. T. Barnsley, John H. Cook, Geo. A. Gilfillan.
KEEFER, GEO. MacFARLAND, Manager, 1102 House Building, Pittsburgh, Pa.	W. H. Wheeler, Henry M. Wilson, Geo. H. Bailey, Jr.
LARNED, J. M., Engineer of Maintenance of Way, 435 Sixth Avenue, Pittsburgh, Pa.	H. T. Porter, Edwin F. Wendt, S. L. Tone.
STILWELL, RICHARD OAKLEY, Supt., Manufacturers Plate Glass Co., Tarentum, Pa.	C. C. Stutz, J. W. Cordes, Chas. Hazel.
WRIGHT, R. S., Contractor for Structural Steel, 1012 Bessemer Building, Pittsburgh, Pa.	G. H. Danforth, F. L. Garlinghouse, John L. Mullin.
SANG, ALFRED, Vice-President, Garland Nut & Rivet Co., Sewickley, Pa.	K. F. Stahl, C. B. Murray, H. L. Collins.

New members who joined the Society in February:

FARNHAM, THADDEUS LOOMIS, Salesman, 1667 Frick Annex, Pittsburgh, Pa.	Richard Khuen, C. P. Howard, J. W. Cordes, Jr.
REED, WILLIAM EDGAR, Designing Eng., Westinghouse Electric Co., East Pittsburgh, Pa.	C. F. Scott, S. M. Kintner, W. A. Bole.

The following resignations were accepted:

Allen, W. J.	Hallsworth, Herbert.
Bates, Onward.	Parker, Wm. M.
Baltzell, W. H.	Page, Henry S.
Esselius, Eric S.	Whitten, Ernest P.

The following resignations were accepted conditionally:

Gellatly, Bert.	Sloan, J. S.
Rankin, Harry H.	Sprecher, Clay.

The following applications for membership were acted upon favorably:

FOR ACTIVE MEMBERSHIP.

	ENDORSED BY
HYDE, WILLIAM H., Contractor and Engineer, 51 Lincoln Avenue, Bellevue, Pa.	Thos. H. Johnson, Wm. G. Wilkins, Frank Wilcox.
MOUNTAIN, JAMES LeROY, Assistant Engineer, Vesta Coal Co., Coal Center, Pa.	W. E. Dickson, S. A. Scott, A. C. Beeson.
SHUMAN, JESSE JAY, Inspecting Engineer, Jones & Laughlin Steel Co., Pittsburgh.	John L. Haines, Robert Geddis, J. L. Klindworth.
LEWIS, W. H., Genl. Supt. Aliquippa Works, Jones & Laughlin Steel Co., Pittsburgh.	Frank S. Slocum, M. J. Dowling, R. B. Kernohan.
STOCKWELL, RUPERT KENNEDY, Draftsman, National Tube Co., McKeesport, Pa.	Geo. T. Snyder, S. R. Bachtel, E. W. Shinn.

FOR JUNIOR MEMBERSHIP.

JONES, ANDREW USHER, Assistant Chemist, National Glass Co., Monongahela, Pa.	F. L. O. Wadsworth, R. L. Frink, W. E. Dickson.
NORTON, CHARLES ARTHUR, Structural Engineer, Bollinger-Andrews Construction Co., Pittsburgh.	Edw. Wurts, Morgan W. Hall, John N. Carey.

The following deaths were reported:

DAVIS, CHARLES, County Engineer, Allegheny County. Joined Society January, 1880—Died, February 21, 1907.

IRVINE, JAMES A. M., with Mc-Clintic-Marshall Construction Company, Pittsburgh. Joined Society January, 1903 —Died January 11, 1907.

Other routine business was transacted and the Board adjourned at 10:00 P. M.

MONTHLY MEETING OF THE SOCIETY.

The 273rd regular monthly meeting of the Society was held at 8:00 P. M. Tuesday, March 19th, 1907.

President Kintner presiding: 40 members and visitors being present.

There being no business to transact, the President introduced the speaker of the evening, Mr. Frederick L. Garlinghouse, of the Jones & Laughlin Steel Co., who read a paper on The Automobile.

Mr. Flint, who was to have been present and read a paper on "International Combustion Engines," having been unavoidably detained, the next paper of the evening, prepared by Mr. H. W. Du Puy, of the Pennsylvania Rubber Co., was read by Mr. Livingston.

A paper on "Automobile Transmission Gear" was read by its author, E. H. Belden, of the Belden Transmission Co.

The subject was then discussed by Messrs. Trinks, Kent, Smith, Beutner, Perkins, Morse, Phillips, Barnsley and the President.

At the conclusion of the discussion, Mr. Livingston, of the Publication Committee, said:

I am very sorry to recall that our rules do not allow us to offer a vote of thanks to a member of the Society. But I would like to extend my personal thanks to Mr. Garlinghouse for taking me out of the hole, and preparing this paper

for to-night. As you understand, the subject was assigned, and my duty consisted in finding a man to write the paper, the information being volunteered that we did not have a man in Pittsburgh that could handle it. I tried twenty odd in New York, Cleveland, Chicago, etc., and finally came back to Pittsburgh; I think the subject has been beautifully handled, and by a Pittsburgher. Mr. Belden is not a member of the Society, so I would like to make a motion that a vote of thanks be extended to him for his very interesting discussion.

The motion, being duly seconded, was carried unanimously.

On motion, adjourned.

STRUCTURAL SECTION.

The regular meeting of the Structural section was held March 5th, 1907, in accordance with the resolution of the joint committee of the Structural and Mechanical Section, January 28th, and adopted by the Mechanical Section to the effect that the Sections hold meetings on alternate months.

In the absence of the Chairman and Vice-Chairman, Mr. Affelder was called to the Chair, 45 members being present.

The report of the joint committee above was read and on motion adopted.

Mr. Pittman, Vice-Chairman, having entered the room, assumed the chair and conducted the meeting.

Mr. Emil Gerber read a paper on "Some Commercial Features of Structural Engineering," which was discussed by Messrs. Albree, Morse, Lyons, Affelder, Knowles, H. S. Pritchard and F. T. Cadmus.

The meeting adjourned at 9:45 P. M.

EDMUND YARDLEY,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section of the Engineers' Society was held with the Pittsburgh Chapter of the American Chemical Society, at the Carnegie Technical Schools, Pittsburgh, Thursday, March 21st, 1907.

The meeting was called to order at 8:15 P. M., 130 members and visitors being present.

Dr. C. P. Kinnicutt, Director of the Department of Chemistry, Worcester Polytechnic Institute, delivered an illustrated lecture on "Modern Bacterial Methods of Sewage Purification."

Adjourned at 10:00 P. M.

HARRISON W. CRAVER,
Secretary Pgh. Chapter, Am. Chem. Soc.

JAMES A. M. IRVINE.

Born at Pittsburgh, September 8, 1880.
Joined the Society in January, 1903.
Died, January 11, 1907.

Mr. Irvine graduated from Pittsburgh High School in 1897 and started his professional career with the Pittsburgh Bridge Company. In September, 1900, he accepted service with the Shiffler Bridge Company, and in the course of two or three months took charge of squad, which position he retained after the Company was absorbed by the American Bridge Company, going to Ambridge and remaining until March, 1906, when he resigned to accept a position of higher standard with McClintic-Marshall Construction Company.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXIII MAY, 1907 No. 4

BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Fulton Building, Saturday, April 6th, 1907, at 8:00 P. M., eight members being present.

The following gentlemen joined the Society in April:

Active Members.

	ENDORSED BY
BIRNEY, E. H., Assistant Supt. Rolling Mills, Jones & Laughlin Steel Co. Pittsburgh, Pa.	Frank S. Slocum, R. B. Kernohan, M. J. Dowling.
STILWELL, RICHARD OAKLEY, Supt., Manufacturers Plate Glass Co.. Tarentum, Pa.	C. C. Stutz, J. W. Cordes, Chas. Hazel.
HYDE, WILLIAM H., Contractor and Engineer, 51 Lincoln Avenue. Bellevue, Pa.	Thos. H. Johnson, Wm. G. Wilkins, Frank Wilcox.
MOUNTAIN, JAMES LEROY, Assist. Engineer, Vesta Coal Company, Coal Center, Pa.	W. E. Dickson, S. A. Scott, A. C. Beeson.
SHUMAN, JESSE JAY, Inspecting Engineer, Jones & Laughlin Steel Co., Pittsburgh, Pa.	John L. Haines, Robert Geddis, J. L. Klindworth,
LEWIS, W. H., Gen. Supt. Aliquippa Works, Jones & Laughlin Steel Co., Pittsburgh, Pa.	Frank S. Slocum, M. J. Dowling, R. B. Kernohan.
STOCKWELL, RUPERT KENNEDY, Draftsman, National Tube Co., McKeesport, Pa.	Geo. T. Snyder. S. R. Bachtel, E. W. Shinn,

Juniors.

NORTON, CHARLES ARTHUR, Struct. Engineer. Bollinger-Andrews Construction Co., Pittsburgh, Pa.	Edw. Wurts, Morgan W. Hall, John N. Carey.
JONES, ANDREW USHER, Assistant Chemist, National Glass Co., Monongahela, Pa.	F. L. O. Wadsworth, R. L. Frink, W. E. Dickson.

The following resignations were accepted:

GALLATLY, BURT, RANKIN, H. H., SPRECHER, CLAY.

The death of D. L. Macomber, Pittsburgh Representative of the Pratt & Whitney Company, was announced.

The following applications were favorably acted on:

Applicants for Active Membership.

	ENDORSED BY
CLARK, CLARENCE PHILO, Engineer of Construction, 241 Miller Street, Mt. Oliver Station, Pittsburgh.	J. L. Klindworth, A. A. Lane, G. K. Newbury.
DODDS, ALEX. WALKER, Salesman, Lunkenheimer Company, Cincinnati, Ohio, 618 Park Building, Pittsburgh.	A. W. Crouch, T. B. Wylie, G. W. Barnes.
VINCENT, LEWIS, Erecting Engineer, 416 Little Street, Sewickley, Pa.	H. M. Wilson, W. C. Coffin, F. R. Sites.

Price of Proceedings—

It was directed that when the number of Proceedings left on hand is reduced to twenty numbers, exclusive of those wanted for binding, the Secretary is authorized to raise the price of those remaining to $1.00 per number.

Further: It was directed that the author of a paper can order (in addition to the twenty-five copies to which he is already entitled) as many more as he wishes, for which he is to pay cost—5 cents each—*provided his order is in the hands of the Secretary before the issue in question goes to press.*

Open Rooms Saturday Evenings—

It was decided to continue to keep the rooms of the Society open during the summer months, on Saturday evenings.

Society Badge—

The Board decided to change the ground of the Society Badge from a dark oxide to a blue enamel.

Adjourned at 10 P. M.

MONTHLY MEETING OF THE SOCIETY.

The 274th regular monthly meeting of the Society was held at 8 P. M., Tuesday, April 16th, 1907, President Kintner presiding; 60 members and visitors being present.

The minutes of the previous meeting were read and approved.

There being no other business before the meeting the President introduced Mr. W. C. Cronemeyer, the pioneer of the Tin Plate Industry in this country, who read a paper on the "History of the Development of the Manufacture of Iron and Steel Sheets."

This was followed by a paper on "Sheet Metal Manipulation," by Mr. Frank I. Ellis, Chief Engineer, United Engineering and Foundry Co., which was read by Mr. F. C. Biggert, Jr., of that company.

The papers were then discussed by Messrs. Winter, Starrett, Klindworth, Hirsch, Babbett and Moore.

At the conclusion of the discussion, on motion of Mr. Livingston, of the Publication Committee, a vote of thanks was tendered Mr. Cronemeyer, who is not a member of the Society, for his interesting paper.

The meeting adjourned at 10:00 P. M.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section was held at the Society's Rooms, at 8 P. M., Tuesday, April 2, 1907, this being the second meeting of this Section for the year. Thirty-five members and visitors were present.

The meeting was called to order by the Chairman, Summer B. Ely, at 8:15 P. M.

The Chairman stated that the By-Laws of the Section were not in harmony with the new By-Laws as adopted by the Society at the first of the year; and it was necessary to make some changes in them in order that they might conform. The

election of the Secretary for the Section, for one thing was out of harmony with the By-Laws of the General Society.

On motion the following committee was appointed by the Chair to revise the By-Laws of the Section and report at the next meeting:

Chester B. Albree, Chairman.

Lee C. Moore. A. Stucki.

Mr. Lee C. Moore then read a paper on the subject of "Mining Coal," which was discussed by Messrs. H. K. Myers, Lewis, Albree. H. W. Myer, Schultz, Schellenberg, Armstrong, Whiteman and McEwen.

On motion adjourned.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held at the rooms of the Society, Fulton Building, with the Pittsburgh Chapter of the American Chemical Society, at 8 P. M. Thursday, April 18th.

The meeting was called to order by Chairman H. D. James, fifteen members being present.

A paper on the "Equilibria Between Nitrogen Bases and Organic Acids in Solution" was read by Dr. Herbert F. Sill. At the conclusion of the paper it was discussed by several members of the Society, and a vote of thanks was unanimously tendered Dr. Sill.

The meeting adjourned at 10:00 P. M.

EDMUND YARDLEY,
Secretary.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII   JUNE, 1907   No. 5

MONTHLY MEETING OF THE SOCIETY.

The 275th regular monthly meeting of the Society was held at the Society Rooms, Fulton Building, Tuesday, May 21st, 1907, at 8:00 P. M. President Kintner in the chair and 55 members and visitors being present.

The minutes of the previous meeting were read and approved.

Two very important papers were read before the Society: One on the "Process of Coal Washing," by Mr. Samuel Diescher, Past President of the Society; the other by Mr. W. G. Wilkins (also a Past President), on the "Description of Washing Plants in Operation."

The discussion which followed the reading of these papers was participated in by Messrs. Anderson, Babbitt, Koch and Stucki.

Adjourned at 10 P. M.   EDMUND YARDLEY,
Secretary.

MEMBERSHIP.

ADDITIONS IN MAY.

DATE OF MEMBERSHIP

Clarence Philo Clark, Engineer of Construction, 241 Miller Street, Mt. Oliver Station, Pittsburgh .... May 11, 1907

Alex. Walker Dodds, Salesman, Lunkenheimer Co., Cincinnati, Ohio, 618 Park Building, Pittsburgh............... May 11, 1907

Lewis Vincent, Erecting Engineer, 416 Little Street, Sewickley, Pa...May 11, 1997

Changes of Addresses.

A. L. Bobbs, of Heller & Wilson, No. 15 Second St., San Francisco, Cal.
Louis P. Blum, 204 Broadway, Allegheny, Pa.
J. G. Chalfant, 25 Court House, Pittsburgh.
W. D. Chester, 1110 Farmers Bank Building, Pittsburgh.
E. E. Erickson, 348 Broadhead St., Easton, Pa.
John L. Klindworth, 24 Bayne Ave., Bellevue, Pa.
W. H. Lewis, Jones & Laughlin Steel Co., Pittsburgh.
F. V. McMullin, 1301-A Walnut St., Edgewood Park, Pittsburgh.
F. S. Martin, 309 Hutchinson St., Swissvale.
C. T. Myers, 419 Tenth St., Racine, Wis.
Wm. L. Siebert, Culebra, Canal Zone.
R. K. Stockwell, Refining & Mining Co., Salt Lake City, Utah.
Walter A. Wheeler, 604 East End Ave., Wilkinsburg, Pa.
B. Wiley, 123 N. Negley Ave., Amber Club, Pittsburgh.

Resignations.

	Date of Membership
Levi G. Stitts, 152 Franklin Ave., Vandergrift, Pa.	Mar. 1903
John S. Sloan, Coraopolis Light Plant, Coraopolis, Pa.	Oct. 1904

MEETING OF BOARD OF DIRECTORS, MAY 11th.

The regular monthly meeting of the Board of Directors was held at the Society Rooms, Saturday, May 11th, 8:00 P. M.

The following gentlemen were elected members:

	Endorsed by
Clark, Clarence Philo, Engineer of Construction, 241 Miller Street, Mt. Oliver Station, Pittsburgh.	J. L. Klindworth, A. A. Lane, G. K. Newbury.
Dodds, Alex. Walker, Salesman, Lunkenheimer Company, Cincinnati. Ohio, 618 Park Building, Pittsburgh.	A. W. Crouch, T. B. Wylie, G. W. Barnes.
Vincent, Lewis, Erecting Engineer, 416 Little Street. Sewickley, Pa.	H. M. Wilson, W. C. Coffin, F. R. Sites.

The following applications for active membership were favorably acted on, and ordered published to the Society:

	ENDORSED BY
ALLEN, JOHN BOWEN, Civil Engineer, 910 Fraklin Street, Wilkinsburg, Pa.	J. H. McRoberts, B. K. Elliott, R. T. McMasters.
FISHER, FRANCIS POWELL, Mechanical Eng., Philadelphia Company, Pittsburgh.	E. D. Leland, Wm. M. Welch, R. S. Orr.
MITCHELL, RUSSELL AULT, Agent, Graphi-Carbon Paint & Color Co., Hartje Building, Pittsburgh.	A. L. Hoerr, S. P. Grace. W. A. Cornelius.

On motion of Mr. Lyons, the policy of insurance which expires May 18th, was ordered renewed. This makes the amount now carried by the society on its furniture and books $8,000, for three years up to March, 1910.

The question of Medals for Papers before the Society was taken up, and it was resolved that the Society will award two medals for the best papers read before it. One medal to be of gold of the value of $25.00; the other medal to be of silver, coined from the same die, and of the same size and pattern. The rules governing the awards of the medals, as finally adopted, were as follows:

1. The awards are to be made by the Board of Directors, on the recommendation of a committee of three, appointed by the President, from its members.

2. The medals are to be awarded only to members of the Society in good standing. Both medals shall be open for competition to all classes of members.

3. Only papers presented at regular meetings of the General Society during the current year, and printed in the Proceedings are eligible for competition.

4. No person shall receive both medals in any one year.

5. The Directors can refuse to grant either or both medals in any year when no paper deemed worthy is presented.

6. The medal shall be awarded at the Annual Meeting following the end of the fiscal year.

7. The recipient's name and the year of award shall be engraved on each medal, and suitable designation of medalists

shall be made annually in the published Membership List and their names enrolled on a roll of honor displayed in the Society House.

Meeting adjourned.

STRUCTURAL SECTION.

The regular Bi-Monthly meeting of the Structural Section was held at the Society Rooms, Fulton Building, May 7, 1907, at 8:00 P. M., 35 members and visitors being present.

The meeting was called to order by the Chairman, E. W. Pitman.

The Chairman called the attention of the Section to the fact that the By-Laws do not conform in some respects with the new By-Laws of the General Society, whereupon a committee of three, consisting of Messrs. Willis Whited, G. H. Danforth, Andrew Kerr, was appointed by the Chair to report a revision of the Section By-Laws to conform with the By-Laws of the general Society, this Committee to report within the next month.

There being no other business before the Society the discussion of the subject of "Structural Shop Costs" was taken up, Mr. Danforth leading in the discussion and being followed by Messrs. Walter C. Kerr, Kratzer, Whited, Chester B. Albree, McEwen, Stucki, Wilkerson and the Chairman.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section of the Engineers' Society was held with the Pittsburgh Chapter of the American Chemical Society, at the Carnegie Technical Schools, Pittsburgh, Thursday, May 23rd, 1907, at 8:00 P. M.

Mr. J. M. Camp read a paper on "A New Shaking Device for Chemical Laboratories."

Mr. J. Kent Smith delivered an address on the subject of "Vanadium."

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII JULY, 1907 No. 6

MONTHLY MEETING OF THE SOCIETY.

The 276th regular monthly meeting of the Society was called to order by President Kintner at 8:10 P. M. on Tuesday, June 18, 1907, 60 members and visitors being present.

The minutes of the previous meeting were read and approved.

There being no other business before the Society, the paper of the evening, "The Sewerage Problem of Western Pennsylvania," was taken up. Mr. Morris Knowles outlined the general scope of the subject, and was followed by papers "On Recent Legislation," by Herbert Snow, and "Present Condition of Municipal Sewerage System of Pittsburgh," by I. Charles Palmer.

President Kintner then called upon some of the visitors present: Dr. Adolph Koenig, member of the Advisory Board of State Department of Health; Dr. Edwards, Superintendent of the local Bureau of Health; Dr. Weber, Chairman of the Committee of Councils on the Filtration Plant; Mr. O. B. Craig, Chairman of the Street Committee of the Borough of Edgewood.

The subject was then further discussed by Messrs. J. P. Leaf, Willis Whited and V. M. Hokanson. Dr. Snow, by request, gave a succinct statement of what had been done in other cities of the State.

Mr. Wilkins explained that the Chamber of Commerce has appointed a committee to consider the subject and make a report with the view of helping to educate the people of this city on the subject.

At the close, Mr. Livingston, of the Programme Committee, moved a vote of thanks to Mr. Snow and Mr. Palmer (not members of the Society) for their interesting and instructive papers.

Adjourned.

MEMBERSHIP.

Additions in June.

	DATE OF MEMBERSHIP
Keefer, George McFarland, Manager Pittsburgh Office, Rensselaer Mfg. Co., 1102 House Building, Pittsburgh	Mar. 9, 1907
Allen, John Bowen, Civil Engineer, 910 Franklin Street, Wilkinsburg, Pa.	June 15, 1907
Fisher, Francis Powell, Mechanical Engineer, Philadelphia Co., Pittsburgh	June 24, 1907

MEETING OF BOARD OF DIRECTION, JUNE 8th.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, Saturday, June 8th, 1907, at 8:00 P. M., eight members and the Secretary being present.

The following gentlemen were elected members:

	ENDORSED BY
ALLEN, JOHN BOWEN, Civil Engineer, 910 Franklin Street, Wilkinsbug, Pa.	J. H. McRoberts, B. K. Elliott, R. T. McMasters.
FISHER, FRANCIS POWELL, Mechanical Eng., Philadelphia Company, Pittsburgh.	E. D. Leland, Wm. M. Welch, R. S. Orr.
MITCHELL, RUSSELL AULT, Agent, Graphi-Carbon Paint & Color Co., Hartje Building, Pittsburgh.	A. L. Hoerr, S. P. Grace, W. A. Cornelius.

The following applicants were approved by the Board and will be voted for on July 6th:

For Active Membership.

	ENDORSED BY
BEYER, HERMAN E., Representative, Southwark Foundry and Machine Co., 804 Frick Building, Pittsburgh.	Julian Kennedy, R. A. McDonald,
BOILEAU, JOHN W., Geologist Engineer, 607 Park Building, Pittsburgh.	F. A. McDonald, Emil Swensson, G. W. Schluederberg.
DAVIDSON, JAMES STANLEY, Checker and Foreman, National Tube Co., Pittsburgh, h. No. 30 Washington Ave., Bellevue, Pa.	P. C. Patterson, M. P. Clark, G. H. Winslow, H. C. Cronemeyer.
SMITH, CAMERON C., Prest. & Gen. Mgr., Union Steel Casting Co., Pittsburgh.	Chester B. Albree, Charles D. Marshall, H. H. McClintic, S. B. Ely.
SPILKER, HENRY P., President, Sterrit-Thomas Foundry Co., 32d and Smallman Sts., Pittsburgh.	Victor Beutner, Lee C. Moore,
RADER, B. H., Sales Agent, Universal Portland Cement Co., 524 Frick Building, Pittsburgh.	C. C. Stutz, B. H. Taylor.

The Publication Committee exhibited a design for the medal voted at the May meeting (Minutes, page 47), which had been arranged so that one design would answer for both the gold and silver medals. The Secretary was ordered to go ahead and have the die made by Heeren Brothers at an expense of $35.00.

A communication from Director A. R. Raymer was received explaining his inability to attend the meetings of the Board and the Secretary was directed to write to him so as to get a more explicit reply from him.

Vouchers for $896.42, as per report of Finance Committee, were approved for payment.

Adjourned. EDMUND YARDLEY,
Secretary.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section was held at the Society rooms, Fulton Building, Tuesday, June 4th, at 8:00 P. M.

The meeting was called to order by Chairman Ely, 60 members and visitors being present.

The minutes of the last meeting were read and approved.

The report of the committee to revise the by-laws was presented by Mr. Chester B. Albree, and was read by the Secretary. Under the rules the Chairman ordered the report to lie over until the next meeting for action. The Secretary stating that it would be necessary to have these By-Laws for the purpose of printing in the Membership List before the next meeting, on motion of Mr. Albree, duly seconded, it was resolved that the amended By-Laws in the form submitted by the Committee, be approved as far as they may be, at the present meeting; the question of their final adoption going over under the rule.

Mr. J. Kent Smith (non-member) favored the Section with an address on the subject of "Vanadium."

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held at the rooms of the Society, Fulton Building, on Thursday, June 20th.

The meeting was called to order by Chairman Chas. H. Rich, 24 members and visitors being present.

The minutes of the last meeting were read and approved.

Dr. F. C. Phillips reported progress on behalf of the Alloy Committee. Dr. James, from the Programme Committee, reported that they had made arrangements by which they would expect to have two papers per meeting for the coming year.

Mr. Sylverman reports that in September be will be able to have a proposed trip to the Macbeth Glass Works.

Papers were read by Mr. R. S. Wile on "A New Detinning Process," and Prof. Fred Crabtree on "The Melting Points and Fluidity of Titaniferous Slags."

After discussion, on motion of Mr. Rich, a vote of thanks was tendered the two gentlemen, which was unanimous.

Section adjourned at 10:30 P. M.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII OCTOBER, 1907 No. 7

MONTHLY MEETING OF THE SOCIETY.

The 277th regular monthly meeting of the Society, being the first after the Summer vacation, was called to order by President Kintner at 8:15 P. M., on Tuesday, September 17th; 70 members and visitors being present.

The minutes of the last meeting having been published in the Proceedings, their reading was dispensed with.

The Secretary read the following announcement:

> "There will be an excursion of the American Chemical Society to the Macbeth-Evans Glass Company's plant, Charleroi, Thursday evening, September 19th. A special car will leave the Union Station at 6:30 P. M. Fare for round trip, $1.40."

There being no other business before the Society the paper by Col. T. P. Roberts on "Floods and Means of Their Prevention in Our Western Rivers" (published in our July Proceedings), was discussed, Mr. Roberts making a synopsis of the paper with extracts from it, followed by Mr. Lewis and Mr. Knowles; after which there was a general discussion in which Messrs. Whited, Morse, Swensson, Albree, Gerber, Leaf, S. A. Taylor, Schellenberg, Scott, Hokanson, Flanagan and Godfrey took part.

The meeting adjourned at 10:30 P. M.

MEMBERSHIP.

Additions.

DATE OF MEMBERSHIP

BEYER, HERMAN E., Representative, Southwark Foundry and Machine Co., Frick Building, Pittsburgh.......................... July 6, 1907

BOILEAU, JOHN W., Geologist Engineer, Park Building, Pittsburgh.......................... July 6, 1907

DAVIDSON, JAMES STANLEY, Checker and Foreman, National Tube Co., Pittsburgh, h. No. 30 Washington Ave., Bellevue, Pa.......................... July 6, 1907

MITCHELL, RUSSELL AULT, Agent, Graphi-Carbon Paint & Color Co., House Building, Pittsburgh.......................... June 8, 1907

RADER, B. H., Sales Agent, Universal Portland Cement Co., 524 Frick Building, Pittsburgh.......................... July 6, 1907

SMITH, CAMERON C., President & Gen. Manager, Union Steel Casting Co., Pittsburgh.......................... July 6, 1907

SPILKER, HENRY P., President, Sterrit-Thomas Foundry Co., 32d and Smallman streets, Pittsburgh.......................... July 6, 1907

Changes of Address.

COLLISON, THOS., American Car & Foundry Co., Broad Exchange Bldg., N. Y.

FLEMING, THOS., 501 North Front St., Harrisburg, Pa.

JENNINGS, F. R., Armstrong Cork Co., Lancaster, Pa.

JONES, ANDREW U., St. Johns, New Brunswick, Canada.

MYERS, A. E., 139 Steuben St., Pittsburgh.

VINCENT, LEWIS, 732 N. Mani St., Rockford, Ill.

WAGONER, C. P., Riter-Conley M'fg. Co., Water St., Pittsburgh.

Resignations.

HAYS, J. W., Avalon, Pa.......................... Sept. 1903
MYERS, C. T., Racine, Wis.......................... Dec. 1904
EBERT, HARRY C., Cincinnati, O.......................... June 1902

Deaths.

DAVIES, THOMAS P., Duquesne, Pa.......................... Nov. 1904

MEETINGS OF THE BOARD OF DIRECTION.

July 6, 1907.

Present, Messrs. Kintner, Lyons, Barnsley, Cummings, Riddle, Schellenberger and the Secretary.

The gentlemen proposed for active membership at the June Meeting (see minutes, page 51), were all elected.

Mr. A. R. Raymer, still finding it impossible to attend the meetings of the Board, and wishing his letter of May 8th to stand, his resignation as a member of the Board was accepted.

Vouchers amounting to $734.10 approved by the Finance Committee were authorized paid.

The Board adjourned till the September meeting.

September 14, 1907.

The regular meeting of the Board of Direction, postponed from September 7th, was held September 14th.

Messrs. Lyons, Barnsley, Frost, Cummings, Handy, Schellenberger, Diescher and the Secretary being present.

In the absence of the President, Mr. Lyons presided.

Minutes of the meeting of July 6th were read and approved.

The following applications were favorably acted upon for presentation to the Society and will be voted on November 9th:

	ENDORSED BY
MARTELL, LOUIS H., Manager, Metal Packing Dept., Garlock Packing Co., Ellwood City, Pa.	G. G. Crawford, E. H. Haslam.
SHAW, NORMAN LOWRIE, Asst. Master Mech., Singer-Nimick Plant, Crucible Steel Co., Pittsburgh.	Edward Godfrey, W. L. Shaw.
WITMAN, DWIGHT NEWCOMB, Chemist, Westinghouse Machine Co., Trafford City, Pa.	W. A. Bole, H. L. Barton.

On the recommendation of the Finance Committee the Petit Cash in the hands of the Secretary was increased to $250.00.

The report of the Committee appointed to write up the history of the advertising contract with Mr. Ensign, was received and laid on the table.

On motion of Mr. Barnsley, C. B. Connelly was appointed Director to fill the unexpired term of A. R. Raymer, resigned.

A communication was received from the House Furnishing Committee that they had expended $104.39 in payment of cases for the Library.

Mr. Cummings, from the Publication Committee, reported that they had accepted a proposition from Mr. A. E. Duckham to secure advertisements for the "Proceedings," his compensation to be 10 per cent of the amount received for the same.

Adjourned at 9:30 P. M.

STRUCTURAL SECTION.

The regular Bi-Monthly Meeting of the Structural Section was held Tuesday evening, September 3rd, in the Society Rooms, Fulton Building.

Meeting was called to order by the Vice Chairman, Mr. E. W. Pittman, at 8:30 P. M., 18 members and visitors being present. In the absence of the Secretary, Mr. G. H. Danforth was appointed Secretary pro-tem.

Minutes of last meeting were read and approved.

The report of the Committee appointed to revise By-Laws of the Section, was accepted and the committee was discharged.

The question recurring upon the adoption of the By-Laws as reported, Mr. Knowles moved to substitute Section 4 of Article VIII. of the By-Laws of the Society as follows:

> "Members of a Section must be members of the Society and members of the Society may become members of a Section by notifying the Secretary."

for Article III. of the Committee's report. This being carried the amended report was laid on the table, under the decision of the Chair, subject to adoption at the next regular meeting of the Section.

There being no further business before the meeting, the paper of the evening, on Waterproofing, by Mr. Colbert A. MacClure, was read. The discussion which followed was participated in by Messrs. Blum, Godfrey, McConnell, Schatz, Knowles and Affelder.

Meeting adjourned at 10:45 P. M.

GEO. H. DANFORTH,
Secretary Pro-Tem.

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ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII NOVEMBER, 1907 No. 8

MONTHLY MEETING OF THE SOCIETY.

The 278th regular monthly meeting of the Society was called to order by President Kintner, at 8:15 P. M., Tuesday, October 15, 1907, 70 members and visitors being present.

The minutes of the previous meeting were read and approved.

At the request of the Entertainment Committee, the Secretary announced a social meeting for Wednesday, October 23rd, at which time Messrs. Metcalf and Lewis, Past-Presidents, are expected to give an informal talk. Light refreshments will be served. The balance of the evening will be spent in social intercourse.

The President explained further that it was proposed that this should be one of a series of social meetings which were to be called "Past-Presidents' Nights," and which would give an opportunity for the members, especially the younger ones, to become better acquainted with one another.

At the request of the Publication Committee, the Secretary called the attention of the members to the Engineering Data which are appearing in the Proceedings.

There being no other business before the meeting, Mr. Knute Backlund read a paper on "Construction and Operation of Modern Blast Furnaces," which was illustrated by a great number of blue prints and tracings.

As the hour of 10 had arrived before the conclusion of this paper, no discussion of it took place.

Adjourned at 10:15 P. M.

MEMBERSHIP.

Changes of Address.

BAKER, S. S., Techmont Club, Wilkins Ave., Pittsburgh.
BLEST, M. C., 17 Woodlawn Ave., Bellevue, Pa.
BROSIUS, W. O., 477 Campbell St., Wilkinsburg, Pa.
CARSON, GEORGE C., Vancouver, Wash.
COLLISON, T. A., American Car & Foundry Co., Broad Exchange Bldg., N.Y.
FAWELL, JOSEPH, 363 South Negley Ave., Pittsburgh.
HOWARD, C. P., L. S. & M. S. Railway Bldg., Cleveland, Ohio.
LYONS, J. K., Dorset Hotel, Pittsburgh.
MARTIN, F. B., 109 N. Park St., Bellefountaine, Ohio.
METCALF, WM., 5821 Wilkins Ave., Pittsburgh.
MITCHELL, R. A., 211 House Building, Pittsburgh.
MCALEENAN, G. R., National Tube Co., Pittsburgh.
MCBRIDE, J. S., 275 Arlington St., Youngstown, Ohio.
MCCABE, CHAS. R., 2645 Perrysville Ave., Allegheny, Pa.
MCEWEN, J. A., Mt. Lebanon, Pa.
NEGRU, JACQUES. 1916 Fisher Building, Chicago, Ill.
ORD, WM., Majestic Building, Detroit, Mich.
PENDRY, W. R., 6240 Monroe Ave., Chicago, Ill.
STEWART, JAS. A., 9 Dewey Ave., Edgewood Park, Pa.
WAGONER, C. P., 210 Bellefield Ave., Pittsburgh.
WELDIN, L. C., Brandywine Summit, Pa.
WHEELER, WALTER A., 3331 Olive St., Kansas City, Mo.

Resignations.

	DATE OF MEMBERSHIP
CORCORAN, W. D., Denniston Ave., Pittsburgh	March, 1903
RIDER, F. A., Farmers Bank Building, Pittsburgh	June, 1906
YOUNG, J. P., Youngstown, Ohio	Oct., 1902

MEETING OF BOARD OF DIRECTION, OCTOBER 5th.

The regular meeting of the Board of Direction was held October 5, 1907, at 8 P. M.

Present: Messrs. Kintner, Lyons, Barnsley, Cummings, Riddle, Schellenberg, Handy and the Secretary. The new Director, Mr. C. B. Connelley, appeared and took his seat.

Minutes of the meeting for September 14th were read and approved.

The following applications were favorably acted on for

presentation to the Society and will be voted for at the next meeting, November 9th:

Applicants for Active Membership.

	ENDORSED BY
MACFARREN, WALTER W., Mechanical Eng., for Bollinger Bros., Fulton Building. Pittsburgh.	W. M. Judd, M. W. Hogle, Daniel Carhart.
PINKERTON, ANDREW, Mech. & Elec. Engr., Farmers Bank Building, Pittsburgh.	S. B. Ely, J. L. Merrill, F. R. Dravo.
PRICHARD, HENRY SEWALL, Statistician, American Bridge Co., Frick Building, house Beaver, Pa.	Robert A. Cummings, G. H. Danforth, J. K. Lyons.
RADEUBUSH, WALTER S., Draftsman, Carnegie Steel Co., Isabella Furnaces; house 219 Swissvale Ave., Edgewood Park.	F. L. White, J. P. Collins. James Scott

Applicants for Junior Membership.

	ENDORSED BY
DILLON, FRED PAUL, Draftsman, County Engineer's Office, Pittsburgh; house 103 Harrison Avenue, Avalon, Pa.	J. G. Chalfant, V. R. Covell, Geo. T. Barnsley.
REBEN, MAX LEIPOLD, Civil Engineer, House Building, Pittsburgh; house 416 Atwood Street, Pittsburgh.	W. H. Wheeler, Geo. M. Keefer, L. C. Moore.
SCHMALZRIED, CHARLES JOHN, Lab'y Work, Heyl & Patterson, Pittsburgh; house 25 Amanda Street, Knoxville, Pa.	W. E. Winn, E. J. Mason, C. H. Gisin.

Vouchers for September, expenses, to the amount of $517.87 were approved.

Rent of Auditorium.

The Secretary presented the contract with the Western University of Pennsylvania, approved by the House Committee, for the rent of the Auditorium for the next six months, ending March, 1908, at $25.00 a month. After discussion and direction to the Secretary to find out more definitely the class of students who are to attend, the action of the House Committee was approved.

"Proceedings" to Authors of Papers.

The Secretary having raised the question as to Proceedings to be furnished gratis to parties contributing papers, it

was decided that only parties whose names appeared on the Announcement as contributing papers were to be furnished with the 25 extra copies free; thus, in the case of the October issue, Mr. Lewis to be entitled to 25 copies and Mr. Knowles not, although the remarks of the latter were much more extended.

Discount on Advertising.

A discount of 2% for quarterly bills paid in advance was considered appropriate and was approved.

Adjourned at 9:30 P. M. EDMUND YARDLEY, Secretary.

MECHANICAL SECTION.

The regular bi-monthly meeting of the Mechanical Section was held at the Society's rooms, October 1st, 1907, 35 members and visitors being present.

Minutes of meeting of June 4th, as printed in the Proceedings, were read and approved.

The revised By-Laws, as published in the List of Members, was unanimously adopted.

There being no other business before the meeting a paper on "Coke Drawing Machines and Other Machinery for Use at the Ovens in the Manufacture of Coke," was read by its author, Mr. W. W. Macfarren, and was discussed by Chairman Ely, Messrs. Stucki, Albree and Negru, and Mr. E. H. Abraham, of Uniontown, Pa.

Meeting adjourned at 10:00 P. M.

CHEMICAL SECTION.

The Chemical Section held its meeting for October (17th) in connection with the Pittsburgh Chapter of the American Chemical Society, 25 members being present.

After the transaction of the business of the Chapter, the members listened to an address by Mr. Alfred Sang on "New Methods of Galvanizing; With Introductory Remarks on Zinc and Its Uses."

JOHN G. LANNING.

John G. Lanning, who had long been connected with the steel business in the open hearth departments of various leading companies, was instantly killed in Boston by an elevator accident on July 18. He had been engaged in the manufacture of open hearth steel practically since its beginning in this country, having been employed in connection with one of the earliest successful installations of Siemens-Martin furnaces in the United States. These were located at the Norway Iron Works, at South Boston, and at this plant was manufactured the steel for the plates for the first vessels of the new navy.

Just prior to the great depression in the iron and steel business in 1893 Mr. Lanning operated open hearth plants at Birmingham and Fort Payne, Ala., where it is believed that the first open hearth steel manufactured in the South was made. The severe business depression that then came involved the Fort Payne plant, with others that had been promoted and backed by New England capital, and it was shut down. After this he was superintendent of the open hearth department at the Newburg Works, in Cleveland, Ohio, and left there to take charge of the plant at Clairton, Pa. Latterly, and up to recently, he had been superintendent of the open hearth department at the Lackawanna Steel Works, Buffalo. At the Clairton plant and Lackawanna plant he established records for output by plants of their capacity, which have been referred to in these columns. Outside of his record as an able manager in his line he was a practical designer, constructor and chemist in connection with his special department of metallurgical work.

He was the grandson of John S. Gustin (bearing his name), who was one of the pioneers in the development of the iron business in this country, and who, just prior to and at the time of the Civil War, was well known as a designer and builder of rolling mills, having generally designed and supervised the construction of the Norway Iron Works, at South Boston, as well as mills at Trenton, N. J.; Worcester, Mass.; Toronto, Canada, and other places.

Mr. Lanning had a large circle of friends and acquaintances at the various plants where he has been in charge, who will remember him not only as thoroughly competent in his special line, but as a man of the highest type of honor and fidelity. He leaves a wife and two children.—*Iron Age, July 26.*

Mr. Lanning joined the Society November, 1903.

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ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

Vol. XXIII DECEMBER, 1907 No. 9

MONTHLY MEETING OF THE SOCIETY.

The 279th regular monthly meeting of the Society was called to order by Vice President Lyons, in the absence of the President, at 8:10 P. M., Tuesday, November 19, 1907, 50 members and visitors being present.

The minutes of the previous meeting were read and approved.

The Secretary read an extract from the circular letter of the President, regarding the **Engineering Data** now being published in the Proceedings, after which, there being no further business before the Society, the meeting proceeded to the discussion of the paper by Henry S. Prichard on **The Proportioning of Steel Railway Bridge Members**, which has already been published in the July Proceedings.

After a brief resume of the salient points of his paper by Mr. Prichard, letters were read commenting on it, from C. D. Purdon, Cons. Engr., St. L. & S. F. R. R.; J. P. Snow, Civ. Engr., W. Summerville, Mass.; A. F. Robinson, Bridge Engr. System, A., T. & S. F.; F. E. Turneaure, Dean of University of Wisconsin; J. W. Schaub, Cons. Engr., Chicago.

After which the subject was still further discussed by Messrs. Knowles, Davison, T. P. Roberts, Blum, Flanagan, Stucki, Wilkerson, Ralph Wood and the Chairman.

Meeting adjourned at 10:10 P. M.

Edmund Yardley,
Secretary.

MEMBERSHIP.

Additions.

ACTIVE MEMBERS.

	ENDORSED BY
MACFARREN, WALTER W., Mechanical Eng., Bollinger Bros., Fulton Building, Pittsburgh.	W. M. Judd, M. W. Hogle, Daniel Carhart.
MARTELL, LOUIS H., Manager. Metal Packing Department, Garlock Packing Co., Ellwood City, Pa.	G. G. Crawford, E. H. Haslam, Thomas E. Doyle.
PINKERTON, ANDREW, Mech. & Elec. Engr., Farmers Bank Building, Pittsburgh.	S. B. Ely, J. L. Merrill, F. R. Dravo.
PRICHARD, HENRY SEWALL, Statistician, American Bridge Co., Frick Building; house Beaver, Pa.	R. A. Cummings, G. H. Danforth, J. K. Lyons.
RANDENBUSH, WALTER S., Draftsman, Carnegie Steel Co., Isabella Furnaces; house 219 Swissvale Ave., Edgewood Park.	F. L. White, J. P. Collins, James Scott.
SHAW, NORMAN LOWRIE, Asst. Mast. Mech., Singer-Nimick Plant, Crucible Steel Co., Pittsburgh.	Edward Godfrey, W. L. Shaw.
WITMAN, DWIGHT NEWCOMB, Chemist, Westinghouse Machine Co., Trafford City, Pa.	W. A. Bole, H. L. Barton.

JUNIORS.

	ENDORSED BY
DILLON, FRED PAUL, Draftsman, County Engineer's Office, Pittsburgh; house 103 Harrison Avenue, Avalon, Pa.	J. G. Chalfant, V. R. Covell, Geo. T. Barnesley.
REBEN, MAX LEOPOLD, Civil Engineer, House Building, Pittsburgh; house 416 Atwood Street, Pittsburgh.	W. H. Wheeler, C. M. Keefer, L. C. Moore.
SCHMALZRIED, CHARLES JOHN, Lab'y Work, Heyl & Patterson, Pittsburgh; house 25 Amanda Street, Knoxville, Pa.	W. E. Winn, E. J. Mason, C. H. Gisin.

Changes of Address.

BANKS, J. E., Ambridge, Pa.
BLODGETT, JOHN, Cedar Heights, Cleveland, Ohio.
CARR, JOHN C., 605 Washington Street, Allegheny, Pa.
DAVIS, CHARLES H., South Yarmouth, Mass.
FEWSMITH, WILLIAM L., 733 Copeland Street, Pittsburgh.
JACKMAN, F. S., Pittsburgh Mfg. Co., Pittsburgh.
KIMBALL, F. I., Irwin, Pa.

Resignations.

	DATE OF MEMBERSHIP
DAFT, L. J., 11 Broadway, New York	September, 1897
HUNTING, E. N., Youngstown, Ohio	October, 1905

MEETING OF BOARD OF DIRECTION.

The regular monthly meting of the Board of Direction was held November 9th, at 8:30 P. M., Messrs. Kintner, Lyons, Barnsley, Morse, Connelley, Cummings, Handy and the Secretary being present.

Minutes of the meeting of October 5th were read and approved.

Vouchers for October expenses to the amount of $812.61 were approved.

The question of the delinquent members of the Society was discussed, there being $1,215.00 dues for 1907 yet unpaid; and it was resolved that a notice should be sent to members delinquent for 1906 and 1907 (two years) with a view of dropping from the rolls those who still remained delinquent on January 1, 1908, (By-Laws, Art. III., Sec. 2). The Secretary was directed to send bills to members delinquent for 1907 only on December 1st, and to stamp them across the face **Final Notice.**

The Treasurer was authorized to pay the expense bill of the Supervising Engineer of Cleveland, who comes, by invitation, to address the Society January 14th, on "Smoke Prevention."

STRUCTURAL SECTION.

The regular bi-monthly meeting of the Structural Section was held Tuesday evening, November 5th, Chairman Khuen in the chair, 31 members being present.

The minutes of the last meeting were read and approved.

The matter of the amended By-Laws (See p. 56 f) was then taken up, and on motion of Mr. Wilkerson, the By-Laws, as amended, were adopted.

There being no further business before the Section, the meeting proceeded to the discussion of the subject for the evening: "How to Figure Lattice Bars," which was opened with a paper by Mr. H. S. Prichard, who was followed by

Messrs. T. H. Johnson, Whited, Godfrey, Pittman, McEwen and the Chairman.

Meeting adjourned at 10:15 p. m.

CHEMICAL SECTION.

The Chemical Section held its meeting for November (21st) in connection with the Pittsburgh Chapter of the American Chemical Society, 25 members being present.

There being no business before the Section, the members listened to the reading of a paper on **"Some Theories on the Genesis of the Michigan Copper Deposits,"** by Dr. Gustave Fernekes, after which Dr. Fernekes still further elucidated his subject by answering questions which were propounded by the members present.

ABSTRACT OF MINUTES

Engineers Society of Western Pennsylvania.

VOL. XXIII JANUARY, 1908 No. 10

MONTHLY MEETING OF THE SOCIETY.

The 280th regular monthly meeting of the Society was called to order by President Kintner at 8:15 P. M., Tuesday, December 17th, 1907, 80 members and visitors being present.

The minutes of the previous meeting were read and approved. There being no further business before the Society, the members present listened to a paper by Geo. A. Macbeth on the "History of Glass." He was followed by Dr. Jno. A. Brashear, who took the audience through a "Picture Story" by means of lantern slides; dealing with his subject under the head of "Contributions of Glass to Our Knowledge of the Stellar Universe."

The subject of glass and glass making was then still further discussed by Messrs. F. L. O. Wadsworth, C. C. Stutz, J. O. Handy.

Other papers on the same subject are promised in the near future.

Adjourned at 10:10 P. M.

MEETING OF THE BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's Rooms, Fulton Building, Pittsburgh, Pa., Saturday, December 7th, 1907, at 8:00 P. M.

Present: Messrs. Lyons, Barnsley, Frost, Cummings, Handy, Schellenberg, Connelley, and the Secretary.

In the absence of the President, Vice-President Lyons presided.

The minutes of the meeting of November 9th were read and approved.

Vouchers for December amounting to $954.33 were approved.

The following recommendations from the Publication Committee were approved, after an interchange of ideas upon the subject:

First—The Medal shall be awarded for the paper which is of the greatest value as an original contribution to engineering science.

Second—It is the opinion of the Publication Committee that the paper of Mr. Prichard should be included in the papers considered in the award for Medals, since Mr. Prichard was a member of the Society at the time his paper was presented and discussed (November 19th), though not one at the time it was originally published in the Proceedings, July, 1907.

The bill of Percy F. Smith for extra work on the Proceedings was taken up and debated, and it was finally resolved that Mr. Cummings should be appointed a committee of one to take the matter up with Mr. Smith in connection with the Secretary and report a proposed equitable settlement to the Board at its next meeting.

Adjourned.

EDMUND YARDLEY,
Secretary.

MEMBERSHIP.

Additions.

ACTIVE MEMBER.

	ENDORSED BY
ACKENHEIL, ALFRED CURTIS, Asst. Engr., Pittsburgh Filtration Plant, T. A. Gillespie Co., Aspinwall, Pa.	Robt. Swan, Morris Knowles, Frank Wilcox.

ASSOCIATE.

GILG, HENRY F., Secy. & Sales Mgr., Refined Iron & Steel Co., Pittsburgh.	John W. Landis, N. C. Wilson, T. B. Wylie.

JUNIOR.

CHESS, HARVEY BUCHANAN, JR., Expanded Metal Co., Pittsburgh.	Harvey B. Chess, C. D. Marshall, A. E. Frost.

Changes of Address.

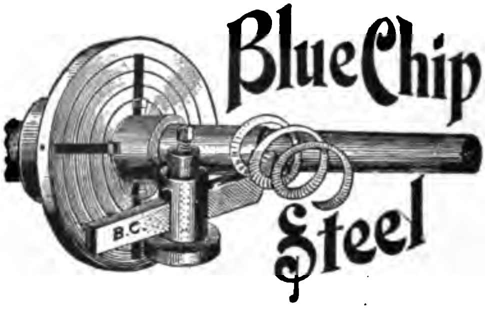
BOBBS, A. L., 36 Dongan St., West New Brighton, N. Y.
BOLTON, H. L., 327 Central Park, W. New York City.
CONVERY, J. J., 3215 N. Howard St., Philadelphia, Pa.
CRUIKSHANK, W., 831 Fulton Building, Pittsburgh.
ELLIOT, BYRON K., 713 College Ave., Pittsburgh.
GOODRICH, C. C., 2 Rector St., N. Y.
HAMPTON. W. W., 525 Bryson St., Youngstown, O.
HENDERSON. J. WESLEY, 439 Third Ave., Pittsburgh.
HENDERSON, HERBERT, Port Arthur, Texas.
HUNTER, H. S., 1019 Jancy St.,, Pittsbnrgh.
JONES, J. J., Westinghouse Bldg., Pittsburgh.
LEWIS, J. L., 5072 Forbes St., Pittsburgh.
McCLELLAND, E. S., 6837 Thomas Bonlevard, Pittsburgh.
McKENNA, A. G., Washington, D. C.
McKINNEY, R. A., Elkhart, Ind.
NEWBURY, G. K., Crafton Station, Pittsburgh.
SANFORD, H. S., 63 Oxford Ave., Buffalo, N. Y.
SNYDER, ANTES LATROBE, 6021 Rodman St., Pittsburgh.
WHEELER, W. H., 1119 Broadway, Indianapolis, Ind.
Wilkerson, T. J., No. 7 Hanover Apartments, McKee Place, Pittsburgh.

Resignations.

	DATE OF MEMBERSHIP
HEISLER, CHAS. L., St. Marys, Ohio	April, 1904

The prudent business man keeps up his advertising

realizing how easy it is to drop out of sight.



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See also page 4

See outside cover

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ordering, the interests of the Society are advanced.

Our little journal is reaching many different

countries it never did before.—*E. K. Morse.*

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Pgh. Industrial Iron Works.

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Car Dumps.
Phillips Mill & Mine Supply Co.
Pgh. Industrial Iron Works.

Car Hitchings.
Phillips Mill & Mine Supply Co.

Castings—Brass and Bronze.
The Lunkenheimer Co.

Castings—Iron.
Pgh. Industrial Iron Works.

Cement.
Alsen Cement Co.
Atlas Portland Cement Co.
Consolidated Rosendale Cement Co.
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Cleveland City Forge & Iron Co.

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Jamison Coal and Coke Company.

Coal Cars.
Phillips Mill & Mine Supply Co.
Pgh. Industrial Iron Works.

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The Lunkenheimer Co.

Compressors—Air and Gas.
Hall Steam Pump Co.

Concrete Mixers.
Pgh. Industrial Iron Works.

Contractors—Concrete.
Cranford Paving Co., The
Cummings, R. A.

Contractors—General.
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Pgh. Construction Co.
Cummings, R. A.

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Pgh. Industrial Iron Works
Somers, Fitler & Todd.

Contractors—Railroad.
Cranford Paving Co., The
The Ferguson Contracting Co.

Contractors—Stone Masonry.
Cranford Paving Co., The

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Westinghouse Electric Co.

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Engines—Hoisting.
Pgh. Industrial Iron Works.
Somers, Fitler & Todd.

Engineers' Supplies.
The Lunkenheimer Co.

Engineers—Contractors.
Cummings, Robert A.

Engineers—Electric.
Somers, Fitler & Todd.

Engravings—Half Tones—Wood Cuts
Robt. Rawsthorne.

Feed Water Heaters and Purifiers.
The Petroleum Iron Works Co.
The Lunkenheimer Co.
Harrison Safety Boiler Works.

Fencing—Iron.
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Kennedy, D. J. Co.

Fire Proofing.
Kratzer & Co., W. N.

Forgings.
Kratzer & Co., W. N.

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Somers, Fitler & Todd.
Westinghouse Machine Co.

Gas Meters.
Pgh. Meter Co.

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Lunkenheimer Co.

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Pgh. Industrial Iron Works.
Somers, Fitler & Todd.

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H. K. Porter Co.

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The Lunkenheimer Co.

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Somers, Fitler & Todd.

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Taylor, Wilson & Co.

Machinists' Supplies.
Somers, Fitler & Todd.

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Westinghouse Machine Co.

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Pittsburg Meter Co.
Builders Iron Foundry.

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Seaman, Sleeth Co.
Mackintosh, Hemphill Co.
United Engineering Co.

Mill Supplies.
Somers, Fitler & Todd.
The Lunkenheimer Co.

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Phillips Mine & Mill Supply Co.
Somers, Fitler & Todd.
Pgh. Industrial Iron Works.
The Lunkenheimer Co.

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Detroit Graphite Co.

Paint—Iron.
Detroit Graphite Mfg. Co.

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Somers, Fitler & Todd.

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Atlas Portland Cement Co.
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Kennedy, D. J. Co.

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Pittsburg Meter Co.

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Somers, Fitler & Todd.

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Hall Steam Pump Co.
Somers, Fitler & Todd.
A. D. Granger Co.

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The Lunkenheimer Co.

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Pgh. Industrial Iron Works.

Riveters.
Mackintosh, Hemphill & Co.

Rolls and Pinions.
Seaman, Sleeth & Co.

Rolling Mill Machinery.
Mackintosh, Hemphill & Co.
United Engineering & Foundry Co.

Rope—Wire.
Pgh. Industrial Iron Works.

Rules—Lumber, Machinists.
Lufkin Rule Co.

Sand Chilled and Steel Rolls.
United Engineering & Foundry Co.

Sand and Gravel.
Kennedy, D. J. & Co.
Rodgers Sand Co.

Silica Sand.
Ellwood Sand Co.

Scales—Drafting.
Lufkin Rule Co.
B. K. Elliott Co.

Screens.
Phillips Mine & Mill Supply Co.
Pgh. Industrial Iron Works.

Sewer Pipe.
Kennedy, D. J. Co.

Shears.
Mackintosh, Hemphill & Co.

Sidewalk Lights.
Kratzer & Co., W. N.

Steel Buildings.
Kratzer & Co., W. N.
Riter-Conley Mfg. Co.
Pittsburgh Construction Co.
Pgh. Industrial Iron Works.

Steel Rolls.
United Engineering & Foundry Co.

Stand Pipe.
The Petroleum Iron Works Co.
Pgh. Industrial Iron Works.

Steam Specialties.
The Lunkenheimer Co.

Steam and Oil Separators—"Cochrane."
Harrison Safety Boiler Works.

Steam and Gas Engines.
Somers, Fitler & Todd.
Westinghouse Machine Co.

Steam Turbines.
Westinghouse Machine Co.

Steam and Water Jet Apparatus.
The Lunkenheimer Co.

Stacks.
The Petroleum Iron Works Co.
Pgh. Industrial Iron Works.

Structural Iron Works.
Kratzer & Co., W. N.

Structural Steel.
Jones & Laughlin Steel Co.

Swedge Nipples.
Somers, Fitler & Todd.

Syphons.
Somers, Fitler & Todd.
The Lunkenheimer Co.

Tanks.
The Petroleum Iron Works Co.
Pgh. Industrial Iron Works.

Tapes, Chain, Steel.
Lufkin Rule Co.
B. K. Elliott Co.

Tar Felt and Roofing.
Kennedy, D. J. Co.

Tar.
D. J. Kennedy Co.

Telephones.
Doubleday-Hill Electric Co.

Tool Steel.
McKenna Bros.

Tools—Machine Shop.
Somers, Fitler & Todd.

Tramways and Wire Rope.
Pgh. Industrial Iron Works.

Transformers.
Doubleday-Hill Electric Co.

Transits.
Pittsburg Instrument & Machine Co.
B. K. Elliott Co.

Unions.
The Lunkenheimer Co.

Turnbuckles.
Cleveland City Forge & Iron Co.
Somers, Fitler & Todd.

Valves.
Somers, Fitler & Todd.
The Lunkenheimer Co.
Jenkins Bros.

Valves—Steam.
The Lunkenheimer Co.
Jenkins Bros.
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Kennedy, D. J. Co.

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Water Heaters.
Harrison Safety Boiler Co.

Water Columns.
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Water Meters.
Builders Iron Foundry.
Pittsburg Meter Co.

Whistles.
The Lunkenheimer Co.

Wire Rope and Fittings.
Hazard Mfg. Co.
Somers, Fitler & Todd.

PROFESSIONAL CARDS.

Attorneys—Patent.
Clay, F. W. H.
Kay, Totten & Winter.

Engineers, Consulting and Construction.
Barnsley, Geo. T.
Cummings, Robert A.
Duckham, A. E.
Swensson, Emil
Metallurgical Laboratory, The
Morse, E. K.
Pittsburg Testing Laboratory
Robt. W. Hunt Co.
Schellenberg, F. Z.
S. V. Huber & Co.

Engineers—Bridge and Structural.
Duckham, A. E.
Swensson, Emil
Morse, E. K.

Engineers—Civil.
Chapin & Knowles.
Cranford Paving Co.
Diescher, S. & Sons.
Donley, Wm. McC.
Duckham, A. E.
Kennedy, Julian
Morse, E. K.
McGrew, J. & E.
Schellenberg, F. Z.
Smith, R. L.
Swensson, Emil.

Educational.
Norwich University.
Rensselaer Institute.

Engineers—Chemical.
Metallurgical Laboratory, The
Pittsburg Testing Laboratory
Robt. W. Hunt Co.
Lehigh Valley Testing Laboratory.

Engineers—Electrical
Rutherfoord, B.

Engineers—Mechanical.
Kennedy, Julian
S. V. Huber & Co.
Wilson, N. C.

Engineers—Mining.
Schellenberg, F. Z.
Smith, R. L.

Engineers—Water Works.
Chapin & Knowles.

Inspectors.
Metallurgical Laboratory, The
Pittsburg Testing Laboratory
Robt. W. Hunt Co.

Patents.
Clay, F. W. H.
C. Ludlow Livingston.
Kay, Totten & Winter.

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Members are requested to consult advertisements in Proceedings when drawing up Specifications.

CALENDAR FOR FEBRUARY.

Saturday,	February	1,	Publication Committee at 3:00 P. M.
Tuesday,	"	4,	Mechanical Section at 8:00 P. M.
"	"	4,	Structural Section, Annual Meeting.
Saturday,	"	8,	Board of Direction at 8:00 P. M.
"	"	15,	Finance Committee at 8:00 P. M.
"	"	15,	Banquet at Hotel Schenley. Tickets $5 00.
Tuesday,	"	18,	General Society at 8:00 P. M.
Thursday,	"	20,	Chemical Section at 8:00 P. M.

Engineers' soc. of
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